VOLUME IIR
NPDES PERMIT RENEWAL APPLICATION

MIXING ZONE DEMONSTRATION

Prepared for:

AMOCO OIL COMPANY
WHITING REFINERY
Whiting, Indiana

Prepared by:

Schafer & Associates

Golden, Colorado

and

The ADVENT Group, Inc.
1925 Lynn Street, Suite 702
Rosslyn, VA 22209

March 1998

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FOREWARD

FOREWORD

This report is Volume IIR of the Amoco Oil Company, Whiting Refinery, application to renew NPDES Permit Number IN0000108. This document supplements Volume II submitted to the Indiana Department of Environmental Management in August, 1994.

Volume IIR provides information to demonstrate that a mixing zone can safely be integrated into the renewed Amoco NPDES Permit. This mixing zone demonstration addresses the requirements of state rules and federal law and guidance. Amoco is providing information based on hydrodynamic and biological field studies, chemical and biological laboratory tests, computer modeling, and literature review of the physical, chemical, and biological characteristics of the receiving water, effluent, and the specific areas of the mixing zone. As a replacement for the current Outfall 001 configuration, Amoco proposes to install and operate a multi-port high-rate diffuser to discharge its treated effluent. A multi-port high-rate diffuser will assure rapid and immediate mixing, thus further minimizing potential aquatic organism exposure. Based on the information provided in this report to satisfy Indiana rules (327 IAC 2-1.5-8 and 5-2-11.4, etc.), a mixing zone is appropriate to be included in Amoco's NPDES permit.

The report is organized into the following sections:

- Section 1 introduces background information on the Amoco Whiting facility, the technical and regulatory basis for allowing a regulatory mixing zone in Lake Michigan, and the applicability of a regulatory mixing zone to Amoco's NPDES permit.

- Section 2 analyzes the mixing zone dispersion of the proposed multi-port high-rate diffuser, using a USEPA-accepted and supported computer model.

- Section 3 demonstrates that a mixing zone meets all Indiana mixing zone regulatory requirements as well as federal guidance. The demonstration includes information on the magnitude and extent of the mixing zone, receiving water and effluent characteristics, and the results of a bioassessment field study.

- Section 4 summarizes the findings of this mixing zone demonstration and recommends the specific mixing zone (size and dispersion ratio) to be incorporated into wasteload allocation procedures necessary to derive water quality-based effluent limits for the NPDES Permit renewal process.

EXECUTIVE SUMMARY

EXECUTIVE SUMMARY
VOLUME IIR

INTRODUCTION

In August of 1994, Amoco submitted an application to renew its NPDES permit that authorizes Amoco to discharge treated water into Lake Michigan. Amoco requested that the 1990 ambient water quality standards be applied at the edge of a proposed mixing zone. Amoco's proposed mixing zone would not result in an increase in concentration or mass over currently permitted levels that are discharged into Lake Michigan from Amoco's state-of-the-art wastewater treatment plant.

This document supplements Volume II ("Mixing Zone Demonstration") of the 1994 permit application. This document (referred to as "Volume IIR") reorganizes the information contained in the original Volume II (referred to as "Volume II") to correspond to new mixing zone rules adopted by IDEM in February of 1997. The substance of the mixing zone demonstration has not changed. While Volume II should remain a part of the permitting docket, Volume IIR is a free-standing document that can be relied on without reference to Volume II. Volume I ("NPDES Permit Renewal Application") has not changed and remains an integral component of the overall application. Volume III ("Permit Limits Derivation Report") completes Amoco's NPDES permit application.

In February of 1997, Indiana adopted new water quality standards (WQS)[1]. The 1997 WQS are based on the United States Environmental Protection Agency's (USEPA) Water Quality Guidance for the Great Lakes System (commonly referred to as the GLI), 40 CFR Part 132. The GLI WQS establish numeric criteria for some specific chemicals and a procedure for developing numeric water quality criteria or values for other specific chemicals. In addition, the GLI WQS specify mixing zone criteria for use in converting the numeric water quality criteria or values into water quality-based effluent limits

[1] Water Quality Standards (WQS) include numeric criteria and narrative standards that address designated uses, antidegradation, criteria development methods, and implementation procedures, including mixing zones. Mixing zones are, in fact, part of WQS.

(WQBELs). Table ES-1 sets forth the 1997 mixing zone criteria verbatim. As demonstrated herein, the 1997 water quality criteria or values should be applied at the edge of a small, well-defined mixing zone.

WHAT IS A MIXING ZONE?

A mixing zone is an area contiguous to a discharge where the treated effluent mixes with the receiving waters. Since water quality criteria or values are exposure-based, they do not apply within a mixing zone; the criteria or values are met at the edge of a mixing zone. Compliance is determined by sampling the effluent prior to discharge and comparing the results to permit limits that account for the dispersion which occurs within the mixing zone.

This technique is common for health-based environmental standards. For example, USEPA promulgates national ambient air quality standards (NAAQS) to protect public health and welfare. 42 USC 7408(a), 7409(a). The various states then adopt rules that apply to specific sources to ensure that the ambient air meets the NAAQS. 42 USC 7410 (a). Individual sources are not required to meet the NAAQS. In fact, individual sources may exceed the NAAQS at the end of a smoke stack and remain in compliance with their individual permits as long as the ambient air meets the NAAQS at the point of exposure (e.g., outside the plant's fenceline). The NAAQS, like water quality standards, are set at a level to protect against excessive exposure in the real world. It is not reasonable (or necessary) to assume that an individual will be perched at the top of a smoke stack for eight hours inhaling the emissions. Likewise, it is not reasonable (or necessary) to assume that a fish will take a position at the end of a discharge pipe and remain there for a sufficient duration to result in any harm. Instead, the regulatory procedures for health-based standards allow for demonstrated dispersion to be included and an emissions limit that accounts for that dispersion.

USEPA and the States, including Indiana, have used mixing zones as a tool for implementing water quality criteria or values since the 1960's. USEPA reaffirmed its view that mixing zones are an appropriate tool for implementing water quality criteria or values in the recently promulgated GLI. IDEM modeled its mixing zone rules on the GLI.[2]

Like the NAAQS, one of the main objectives in applying the water quality standards is to determine a point at which the standards must be met. In the case of the NAAQS, it may be at the fenceline. In the case of the WQS, it is at the edge of a mixing zone. In practice, this means that a dispersion ratio is established at the edge of the mixing zone and is used to translate water quality criteria to an end-of the-pipe limit. For example, with 100:1 dispersion at the edge of a mixing zone, a mass balance of 1 part effluent with 100 parts receiving water (at background concentration) is calculated to develop an end-of-pipe limit, with compliance determined based on samples of the effluent prior to mixing with the receiving water.[3] An end-of-the-pipe limit is necessary because it is often not feasible to obtain compliance samples at the edge of a mixing zone.

WHY ARE MIXING ZONES APPROPRIATE?

USEPA has endorsed mixing zones for four decades. Mixing zones are appropriate given that the water quality criteria are exposure-based and exposure is of very limited duration inside a mixing zone. Water quality criteria include numerical limits based on three principles[4]:

- magnitude of exposure
- duration of exposure, and
- frequency of exposure

Chemical specific and whole effluent toxicity (WET) water quality criteria are based on both the acute (or short-term) effects and the chronic (or long-term) effects on aquatic life. Numeric water quality criteria are developed for specific chemicals and for WET.

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[2] The USEPA GLI and IDEM rules (327 IAC ARTICLE 5) set forth several important limitations on the use of mixing zones.
First, mixing zones are only appropriate if the subject waterbody meets the water quality standards. In other words, there must be assimilative capacity to accommodate the increased loading. Second, mixing zones are not appropriate for substances that bioaccumulate. Third, mixing zones should not be used to adjust any technology-based limits (as opposed to water quality-based limits). Amoco's proposed mixing zone is consistent with these limitations.

[3] Based on a review of approved mixing zones, dispersions can vary significantly from 2:1 to 500:1. The USEPA GLI uses a default mixing zone for lakes of 10:1.

[4] WQS also include narrative standards that address designated uses, antidegradation, and implementation including mixing zones.

This approach prevents impacts from individual chemicals, as well as from the cumulative, additive and/or synergistic effects of the combination of chemicals in the whole effluent.

Acute Aquatic Criteria (AAC) are based on protecting the most sensitive species from acute effects. For instance, Indiana's AAC for chlorides is 860 mg/L *(magnitude)* as a one-hour average *(duration)* concentration, not to be exceeded more than once every three years on average *(frequency).* By contrast, Chronic Aquatic Criteria (CAC) are derived to protect the most sensitive species from chronic effects and are expressed as a specified concentration *(magnitude)* over a four-day average *(duration*), not to be exceeded more than once every three years on average *(frequency).* The Indiana CAC for chlorides is 230 mg/L *(magnitude)* as a four-day average *(duration)* not to be exceeded more than once every three years *(frequency).* Due to the duration and frequency principles underlying the derivation of criteria, the criteria are referred to (by USEPA and others) as "instream criteria", highlighting the fact that these are not to be attained at end-of-pipe. 327 IAC 2-1.5-7.

The numeric water quality criteria are converted into water quality-based effluent limitations (WQBELs) as part of the permitting process. This process considers whether a permit applicant's effluent (as measured at the end-of-pipe) has the reasonable potential to exceed (RPE) an instream water quality criteria. If so, a permit limit should be developed based on a wasteload allocation that accounts for the permittee's discharge, as well as the combined impact of other discharges (point and nonpoint sources) and naturally occurring background concentrations. The permit limit must ensure that the water quality criteria or values will be met in the receiving water.

If a permit applicant demonstrates that it has engineered a mixing zone that meets the regulatory requirements, then, by definition, the mixing zone will not result in exposure for a duration and/or frequency that exceeds a numeric water quality criteria. Thus, permit limits can be developed, taking into account a mixing zone. For example, in many cases the initial momentum from the discharge of effluent into the receiving water minimizes the time organisms would be exposed to concentrations above the magnitude criteria. Though the exposure will exceed the magnitude of the criteria, the duration of exposure can be limited to ensure that there is no adverse effect. USEPA and the states have developed rules and guidance over the years to determine the limitations on the duration of exposure that are necessary to protect human health, aquatic life, and wildlife. IDEM has adopted these rules as part of the GLI. If an applicant meets the requirements set forth in 327 IAC 5-2-11.4(b)(4) (see Table ES-1), it has by definition established that the duration of exposure within a defined mixing zone will not interfere with the waterbody's designated uses.

IS AMOCO'S PROPOSED MIXING ZONE APPROPRIATE?

Amoco's proposed mixing zone is appropriate because it meets all of the documentation and demonstration requirements set forth in Indiana rules (see Table ES-1). Addressing these regulatory demonstration criteria calls on two different disciplines: hydrodynamics and biology. Amoco's hydrodynamic and biological studies are discussed in this document and summarized below.

The hydrodynamic investigations involve studies of the physical properties of mixing. Amoco has previously demonstrated that its present discharge (Outfall 001) provides significant mixing through the dispersion created by its existing discharge configuration. Nonetheless, Amoco is proposing to install a multi-port submerged high-rate diffuser to enhance mixing and to reduce the size and area of the resulting mixing zone. A diffuser is a structure engineered to enhance mixing by discharging effluent at a relatively high velocity into the water column and directed away from the lake bottom.

Amoco proposes to install the multi-million dollar diffuser at a depth of approximately 30 feet at a location approximately 3,500 feet northeast of the present side-channel outfall. The rationale for this site is to maximize mixing with ambient waters by locating the diffuser in deeper waters where more water volume is available for rapid mixing than is available than the current Outfall 001. After installation of the diffuser, the treated effluent will be pumped through a 3,500-foot feeder pipe and discharged at high velocities (e.g., 10 feet/second) through ten small ports evenly spaced over the last 90 feet of the pipe (the diffuser header).

To determine the dispersion ratio that can be achieved by the proposed diffuser, Amoco researched historical records, conducted its own field measurements, and consulted with widely recognized experts. The data gathered were entered into an USEPA-endorsed computer model used to project mixing (CORMIX2). Based on the modeling and field studies, Amoco proposes a mixing zone that is equivalent to the discharge-induced mixing zone under Indiana rules. This area encompasses a 50-foot radius around the diffuser. At the edge of this zone, the effluent is dispersed by a 54:1 ratio. Organism exposure inside this mixing zone will be less than the duration component used to derive water quality criteria. In fact, exposure time for free floating organisms in the discharge-induced mixing zone is less than 90 seconds, which is significantly less than the one-hour or four-day exposure duration component used to determine acute or chronic water quality criteria, respectively. Thus, to establish daily maximum and monthly average end-of-pipe limits, a mass balance of one part effluent and 54 parts of background receiving water is applied to the instream water quality criteria.

In addition to the mixing hydrodynamics discussed above, Amoco conducted a series of biological assessments of the present discharge location and the proposed diffuser site. These assessments found no evidence of adverse effects to aquatic life or the designated uses of the receiving water at the present site (presented in 1994 Volume II). Given that the proposed mixing zone includes dispersion enhancements when compared to the current discharge (i.e., a diffuser in deeper water and away from shore), the proposed mixing zone will not adversely impact the designated uses of southern Lake Michigan.

The biological assessments evaluated bottom-dwelling, free-floating, and attached aquatic communities. Species from these particular communities were collected, identified, and counted because they are either (a) the most sensitive aquatic communities in the area where mixing between effluent and receiving water occurs, or (b) the most critical communities in the Great Lakes ecosystem food chain. The overall findings from the biological assessment were that the present discharge has not adversely affected aquatic life or the designated uses of the receiving water. With a submerged multi-port high-rate diffuser located in deeper waters, the dispersion effects are enhanced as effluent will be quickly mixed throughout the deeper water column, further minimizing the exposure time for organisms.

CONCLUSION

The hydrodynamic studies and biological assessment, taken together, make a compelling demonstration that Amoco's proposed mixing zone will not cause harm to human health, aquatic life, or wildlife. In fact, reducing the duration of exposure by using a submerged high-rate diffuser renders Amoco's proposed mixing zone more protective of human health, aquatic life, and wildlife than the existing discharge. Under Indiana law, IDEM must include the mixing zone in Amoco's permit because Amoco has met all of the conditions for approval set forth in 327 IAC 5-2-11.4(b)(4).

TABLE ES-1. INDIANA MIXING ZONE CRITERIA

327 IAC 5-2-11.4(b)(4)(A)(i)	Document the characteristics and location of the outfall structure, including whether technologically enhanced mixing will be utilized.
327 IAC 5-2-11.4(b)(4)(A)(ii)	Document the amount of dilution occurring at the boundaries of the proposed mixing zone and the size, shape and location of the area of mixing, including the manner in which diffusion and dispersion occur.
327 IAC 5-2-11.4(b)(4)(A)(iii)	For sources discharging to the open waters of Lake Michigan, define the location at which discharge-induced mixing ceases.
327 IAC 5-2-11.4(b)(4)(A)(iv)	Document the physical including substrate character and geomorphology, chemical and biological characteristics of the receiving waterbody, including whether the receiving waterbody supports indigenous, endemic or naturally occurring species.
327 IAC 5-2-11.4(b)(4)(A)(v)	Document the physical, chemical, and biological characteristics of the effluent.
327 IAC 5-2-11.4(b)(4)(A)(vi)	Document the synergistic effects of overlapping mixing zones or the aggregate effects of adjacent mixing zones.
327 IAC 5-2-11.4(b)(4)(A)(vii)	Show whether organisms would be attracted to the area of mixing as a result of the effluent character.
327 IAC 5-2-11.4(b)(4)(B)(i)	The mixing zone would not interfere with or block passage of fish or aquatic life.
327 IAC 5-2-11.4(b)(4)(B)(ii)	The level of pollutant permitted in the waterbody would not likely jeopardize the continued existence of any endangered or threatened species listed under Section 4 of the ESA or result in the destruction or adverse modification of such species habitat.
327 IAC 5-2-11.4(b)(4)(B)(iii)	The mixing would not extend to drinking water intakes.
327 IAC 5-2-11.4(b)(4)(B)(iv)	The mixing zone would not impair of otherwise interfere with the designated uses of the receiving water or downstream waters.
327 IAC 5-2-11.4(b)(4)(B)(v)	The mixing zone would not promote undesirable aquatic life or result in a dominance of nuisance species.
327 IAC 5-2-11.4(b)(4)(B)(vi)	By allowing the additional mixing: (AA) substances will not settle to form objectionable deposits; (BB) floating debris, oil, scum, and other matter in concentrations that form nuisances will not be produced; and (CC) objectionable color, odor, taste, or turbidity will not be produced.
327 IAC 5-2-11.4(b)(4)(C)	In no case shall a mixing zone for a discharge into the open waters of Lake Michigan be granted that exceeds the area where discharge induced mixing occurs.

SECTION 1

SECTION 1.0
INTRODUCTION

As part of its comprehensive water quality management program, Amoco Oil Company, Whiting Refinery (Amoco) has performed studies to assess the options available to comply with the Indiana Water Quality Standards (327 IAC 2) promulgated on March 3, 1990, and revised February 13, 1997. These state standards have incorporated the requirements of the federal Clean Water Act of 1987 as well as the Final 1995 Water Quality Guidance for the Great Lakes System (40 CFR Part 132). Part of these requirements include application of water-quality based (chemical-specific and whole effluent toxicity) effluent limits, as well as technology-based limits for direct dischargers.

Based on Amoco's water quality studies and the fact that Lake Michigan is in attainment of water quality standards, Amoco concludes that a mixing zone is appropriate to define a point of application for water quality criteria.

Amoco requests an evaluation of the application of a mixing zone for the discharge of treated effluent into Lake Michigan pursuant to 327 IAC 2-1.5-7 and 327 IAC 5-2-11.4 and federal mixing zone guidance. Results of an effluent dispersion analysis and corresponding mixing zone demonstration as part of this request are presented in this report.

1.1 FACILITY DESCRIPTION

The Amoco Whiting Refinery occupies approximately 1,700 acres near the southern end of Lake Michigan as presented in Figures 1-1 and 1-2. The petroleum refinery includes processes such as distillation, catalytic reforming, hydrodesulfurization, catalytic cracking, alkylation, coking, treating, extraction, dewaxing, grease and lube oil production, asphalt production, sulfur recovery, and power generation. The refining throughput varies with product demand and other market considerations, but its capacity averages 410,000 barrels of crude per day. Amoco produces a variety of products including jet fuel, gasoline, diesel fuel, heating fuel, lubricating oils, asphalt, coke, and waxes.

The refinery generates process waters which are continuously treated on-site at an advanced biological wastewater treatment plant (WWTP) as shown schematically in Figure 1-3. (Volume I NPDES Permit Application, submitted August 29, 1994, presents details of the WWTP). Stormwater run-off and recovered groundwater from refinery areas are also treated at the WWTP. The treated effluent is then discharged to Lake Michigan through a National Pollutant Discharge Elimination System (NPDES) permitted outfall (Outfall 001). The refinery withdraws water from Lake Michigan for use in process units and for once-through cooling. The once-through noncontact cooling water is discharged through NPDES Outfall 002. Both outfalls are regulated by NPDES Permit IN0000108 (the NPDES Permit) which became effective on April 1, 1990. The effluent flow from Outfall 001 ranged from 13 (long-term average) to 23 (maximum monthly average) million gallons per day (mgd) during 1991 to 1994 (Volume I NPDES Permit Application, submitted August 29, 1994). For the same time period, the average flow from Outfall 002 ranged from 110 to 120 mgd.

The NPDES Permit has limits for Outfall 001 derived from technology-based effluent limits, which are presented in Table 1-1. Amoco has consistently attained these permit limits with high quality effluent that meets or is better than "Best Available Technology" (BAT) effluent requirements, as seen by the historical WWTP plant performance also indicated in Table 1-1. It is anticipated that the new permit will contain effluent limits based on the Indiana Water Quality Standards as well as the previously applicable technology-based standards. Amoco is not requesting a mixing zone for technology-based standards. As part of the permit renewal application, Amoco is submitting this report to demonstrate an appropriate implementation of a mixing zone for application of the Indiana water quality standards consistent with 327 IAC 2-1.5-7 and 5-2-11.4.

1.2 WATER QUALITY MANAGEMENT PROGRAM

To meet the goals of the Indiana water quality laws, Amoco developed a comprehensive water quality management program including the elements presented in Table 1-2. For example, wastewater treatment has been optimized by supplementing the aeration system in the bio-tanks (1995) and upgrading the final filters (1996). Details of some of the activities listed in Table 1-2 can be found in Volume I NPDES Permit Application, submitted August 29, 1994. This current report (Volume IIR) presents a discussion of the program elements relating to defining the point of application for receiving water quality criteria through delineation of a mixing zone in Lake Michigan for Outfall 001.

1.3 APPROPRIATENESS OF MIXING ZONE FOR THE AMOCO WHITING REFINERY

As part of the water quality management program, Amoco considered several factors prior to proceeding with a mixing zone demonstration. There are generic stipulations presented in USEPA guidance[5] to assess the appropriateness of using a mixing zone to define the point of application of criteria and to develop discharge limits. In light of these USEPA stipulations, Amoco presents the following responses to the appropriateness of using a mixing zone for Outfall 001 permitting. As discussed previously, implementation of a mixing zone for the Amoco facility is not a substitute for BAT wastewater treatment. Amoco has demonstrated that based on USEPA test methods the combined effect of constituents discharged from Outfall 001 is not acutely toxic (presented in Volume I NPDES Permit Application, submitted August 29, 1994). Lake Michigan meets the water quality criteria for its designated uses for the constituents listed in Table 1-4, (i.e., background concentrations are less than the most stringent criteria), hence assimilative capacity exists. The presence of assimilative capacity for these constituents allows the use of a mixing zone in establishing discharge limits. In addition, the proposed mixing zone covers a limited area and will not impair the integrity of the receiving waterbody, as further documented in Sections 2 and 3.

Furthermore, the federal recommendation of mixing zone use to define the point of application for criteria has to be recognized by the state. Indiana concurs with federal guidance that water quality criteria apply in the receiving water and not at end-of-pipe as discussed in the Sections 1.4 and 1.5. Indiana defines a mixing zone as follows:

> ***327 IAC 2-1.5-2 (55) Definitions***. *"Mixing zone" means an area contiguous to a discharge where the discharged wastewater mixes with the receiving waters. Where the quality of the effluent is lower than that of the receiving waters, it may not be possible to attain within the mixing zone all beneficial uses which are attained outside the zone. The mixing zone should not be considered a place where effluents are treated.*

[5] USEPA, 1991, Technical Support Document for Water Quality-based Toxics Control (TSD), and 1993 Water Quality Standards Handbook, Second Edition (WQSH)

Guidelines in the Indiana Water Quality Standards for demonstrating the appropriateness of a mixing zone in State waters are presented in the following paragraph.

> ***327 IAC 2-1.5-7 Mixing Zone Guidelines***. *"(a) All surface water quality criteria in this rule, except those provided in section 8(b)(1) of this rule, are to be applied at a point outside of the mixing zone as determined under 327 IAC 5-2-11.4 to allow for a reasonable mixture of waste effluents with the receiving waters.*

Indiana does have a prohibition for the use of mixing zones in permitting, hence, Amoco is not requesting (nor does it need) a mixing zone for Indiana-defined bioaccumulative constituents of concern (BCCs).

As a mixing zone is appropriate for Outfall 001, Amoco proceeded to fulfill the Indiana requirements to demonstrate that a mixing zone can be defined and is applicable to assure attainment of water quality criteria. The implementation of a mixing zone will continue to maintain water quality standards for Lake Michigan without requiring unnecessary wastewater treatment and increased multi-media impacts.

1.4 BASIS FOR ALLOWANCE OF A MIXING ZONE

In discussing mixing zones, terminology frequently varies with the intent and context of the discussion. For instance, the use of certain terms may depend on whether the discussion relates to engineering (hydrodynamics and modeling), field assessment (scientific measurements), or laws and guidance (regulatory). Federal and individual state laws and guidances often have specific defined mixing zone terms, therefore, selected terms and their corresponding definition used in this report are presented in Table 1-3.

When a liquid effluent is discharged to a lake, a natural area of mixing is created. This area of mixing is where the effluent commingles, spreads out, and disperses in the receiving water. Initially, mixing is driven by the hydraulic force of the discharged water. This zone is defined as the jet entrainment zone. After the hydraulic energy of the effluent is dissipated, differences in density and relative movement of the spreading effluent and the receiving water body combine for further mixing, described as the transition zone. The jet entrainment zone and transition zone combine to form the near-field mixing zone. Eventually, the natural currents of the receiving waterbody become the dominant force.

This area is defined as the far-field mixing zone. Natural driving physical processes such as flow, density differences, temperature gradients, or variable chemical concentrations, continue to drive mixing between effluent and receiving water in this zone.

Water quality criteria based on Indiana Water Quality Standards are listed in Table 1-4 for metals and conventional constituents. Water quality criteria are defined by three factors:

- magnitude,
- duration, and
- frequency.

These factors are necessary to define criteria to protect the designated use of the waterbody. The criteria consider both the acute (short-term) effects and the chronic (long-term) effects. Short-term and long-term effects are measured through laboratory toxicity bioassay testing of a chemical. Acute criteria are based on protecting the most sensitive species from acute effects and are expressed as Acute Aquatic Criteria (AAC). For example, Indiana's AAC for chlorides is expressed as: 860 mg/L (magnitude) of chlorides as a one-hour (duration) average concentration not to be exceeded more than once every three years (frequency) on average. The Chronic Aquatic Criteria (CAC) are derived to protect the most sensitive species from chronic toxic effects and are expressed as a four-day average concentration. For instance, Indiana's CAC for chlorides is expressed as: 230 mg/L (magnitude) of chlorides as a four-day (duration) average not to be exceeded more than once every three years (frequency) on average.

As stated in 327 IAC Articles 2 and 5, the AAC and CAC, due to their duration (exposure) and frequency (time) elements, are to be met in the receiving water. To ensure protection of the receiving water, the point of application of criteria are:

- AAC at edge of the Discharge-Induced Mixing Zone (DIMZ) (327 IAC 2-1.5-8(b)(1)(E)(i)

- CAC at the edge of the applicable mixing zone (327 IAC 2-1.5-8(b)(2))

Indiana Articles 2 and 5 also state that the Continuous Chronic Criteria (CCC), which includes the CAC as well as any other Tier II chronic criteria, apply at the edge of the "applicable mixing zone"[6]. Similarly, Tier II acute criteria apply at the edge of the "discharge-induced mixing zone" (DIMZ).

The USEPA[7] has determined that travel time through an acute mixing zone (DIMZ) must be roughly less than fifteen minutes if a one-hour average exposure is not to exceed the acute criterion. In addition, USEPA has recommended receiving water flow or velocity design conditions to establish the mixing zone to mimic the three-year return interval. This type of assessment for receiving water quality addresses the magnitude (acute criteria concentration to be attained at edge of DIMZ), duration (rapid mixing of less than 15 minutes to minimize exposure), and frequency (critical/conservative receiving water velocity or flow) of exposure.

To reconcile hydraulic and Indiana regulatory terms, this mixing zone demonstration equates the "discharge-induced mixing zone" to the "jet entrainment zone". The "applicable mixing zone" equates to the "far-field zone" and is also referred to as an "alternate mixing zone"[8] when a site-specific mixing zone demonstration is requested. For a Lake Michigan discharge, the extent of the alternate mixing zone is limited to the discharge-induced mixing zone (327 IAC 5-2-11.4(b)(2)(A)(v)), hence, only one delineated area and one dispersion ratio will apply to the DIMZ. At this point, both the AAC and CAC criteria are to be attained. Therefore, this demonstration delineates the discharge-induced mixing zone for the Amoco Outfall 001.

1.5 INDIANA MIXING ZONE REQUIREMENTS

In February of 1997, Indiana adopted new water quality standards (WQS). The 1997 WQS are based on the USEPA Water Quality Guidance for the Great Lakes System (commonly referred to as the "GLI") 40 CFR Part 132. The GLI WQS establish numeric standards for some specific chemicals and a procedure for developing numeric WQS for other specific chemicals. In addition, the GLI WQS adopt mixing zone criteria for use in converting the numeric criteria into water quality-based effluent limits (WQBELs).

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[6] 327 IAC 2-1.5-8(b)(2) refers to applicable mixing zones and 327 IAC 5-2-11.4(b)(2)(A)(ii) refers to alternative mixing zones in defining where chronic criteria are to be attained.
[7] USEPA, 1991 TSD, and 1993 WQSH
[8] Pursuant to 327 IAC 5-2-11.4(b)(2)(A)(i), (ii), and (iii) and (b)(3)(B)(i) and (ii) and (C)

An applicant must address the following items in an application for a mixing zone:

- Document the characteristics and location of the outfall structure, including whether technologically enhanced mixing will be utilized.
- Document the amount of dilution occurring at the boundaries of the proposed mixing zone and the size, shape, and location of the area of mixing, including the manner in which diffusion and dispersion occur.
- For sources discharging to the open waters of Lake Michigan, define the location at which discharge-induced mixing ceases.
- Document the physical, including substrate character and geomorphology, chemical and biological characteristics of the receiving waterbody, including whether the receiving waterbody supports indigenous, endemic or naturally occurring species.
- Document the physical, chemical, and biological characteristics of the effluent.
- Document the synergistic effects of overlapping mixing zones or the aggregate effects of adjacent mixing zones.
- Show whether organisms would be attracted to the area of mixing as a result of the effluent character.

327 IAC 5-2-11.4(b)(4)(A)(i)-(vii).

IDEM must grant the mixing zone if an applicant demonstrates the following:

- The mixing zone would not interfere with or block passage of fish or aquatic life.
- The level of pollutant permitted in the waterbody would not likely jeopardize the continued existence of any endangered or threatened species listed under Section 4 of the ESA or result in the destruction or adverse modification of such species habitat.
- The mixing would not extend to drinking water intakes.
- The mixing zone would not impair of otherwise interfere with the designated uses of the receiving water or downstream waters.
- The mixing zone would not promote undesirable aquatic life or result in a dominance of nuisance species.
- By allowing the additional mixing: (AA) substances will not settle to form objectionable deposits; (BB) floating debris, oil, scum, and other

matter in concentrations that form nuisances will not be produced; and (CC) objectionable color, odor, taste, or turbidity will not be produced.

- In no case shall a mixing zone for a discharge into the open waters of Lake Michigan be granted that exceeds the area where discharge induced mixing occurs.

327 IAC 5-2-11.4(b)(4)(B)(i)-(vi).

If an applicant documents the required information and demonstrates the listed items, IDEM must grant the request for a mixing zone:

> *...unless the commissioner determines that the mixing zone should be denied based upon a consideration of harm to human health, aquatic life, or wildlife. The commissioner shall evaluate all available information, including information submitted by the public, relevant to the consideration of harm to human health, aquatic life, or wildlife. The commissioner shall identify the harm to human health, aquatic life, or wildlife, and document the rationale for this decision.*

326 IAC 5-2-11.4(b)(4)(B)(6).

If an applicant satisfies its specified obligations under the rule, the burden shifts to IDEM to prove some specific harm that warrants the denial of the mixing zone.

As documented in Sections 2 and 3, Amoco has satisfied its obligation under the rule in demonstrating that a mixing zone is appropriate for Outfall 001.

TABLE 1-1. NPDES OUTFALL 001 DISCHARGE LIMITATIONS AND EFFLUENT QUALITY

PARAMETER	UNITS	1990 PERMIT LIMITS (a)		HISTORICAL PERFORMANCE (b)	
		MONTHLY AVERAGE	DAILY MAXIMUM	MONTHLY AVERAGE	DAILY MAXIMUM
TBOD5	lbs/day	4,161	8,164	721	3,580
TSS	lbs/day	3,646	5,694	2,059	4,904 (c)
COD	lbs/day	30,323	58,427	7,973	18,515
Oil & Grease	lbs/day	1,368	2,600	463	1,594
Phenolics (4AAP)	lbs/day	20.33	73.01	3.1	17.9
Ammonia as N	lbs/day	1,030	2,060	551	1,446
Sulfide	lbs/day	23.1	51.4	6.7	14.3
Total Chromium	lbs/day	23.90	68.53	2.4	5.3
Hexavalent Chromium	lbs/day	2.01	4.48	0.6	1.2

Notes:

(a) 1990 Permit Limits are based upon previous permit effluent limitations since they were more stringent than BPT/BAT limits.

(b) Historical performance based on monthly DMR data for April 1991 to April 1994 (consistent with Form 2C).

(c) Daily maximum does not include a 24-hour time period when the WWTP experienced a known upset condition on August 31, 1993.

BPT - Best Practicable Control Technology Currently Available

BAT - Best Available Technology Economically Achievable

TABLE 1-2. WATER QUALITY MANAGEMENT PROGRAM ELEMENTS

ELEMENT	DATE INITIATED	DATE COMPLETED
EFFLUENT CHARACTERIZATION		
- Chemical Specific	1990	Ongoing
- Flow/Hydraulics	1991	Ongoing
- Whole Effluent Toxicity Studies	1991	1993
TREATABILITY STUDIES	1991	1994
SOURCE CONTROL	1991	Ongoing
WWTP UPGRADES	1991	Ongoing
BENZENE NESHAP CONTROL PROJECTS	1990	1994
SARA (TRI) EMISSION REDUCTION PROJECTS	1990	Ongoing
ZEBRA MUSSEL CONTROL	1992	Ongoing
STORMWATER QUALITY CONTROL PROJECTS	1992	Ongoing
RECEIVING WATER CHARACTERIZATION		
- Hydraulics	1990	Ongoing
- Chemical Bioavailability	1991	Ongoing
- Aquatic Biological Community & Habitat Characterization	1992	Ongoing
- Background Water Quality	1991	Ongoing
POINT OF APPLICATION ESTABLISHMENT FOR IN-STREAM WATER QUALITY CRITERIA (Mixing Zone Delineation)	1990	1997
WASTELOAD ALLOCATION DETERMINATION	1992	1997
SITE-SPECIFIC WATER QUALITY CRITERIA ASSESSMENT	1991	1993
PRELIMINARY DIFFUSER DESIGN	1994	1994

TABLE 1-3. MIXING ZONE TERMINOLOGY FOR LAKE MICHIGAN

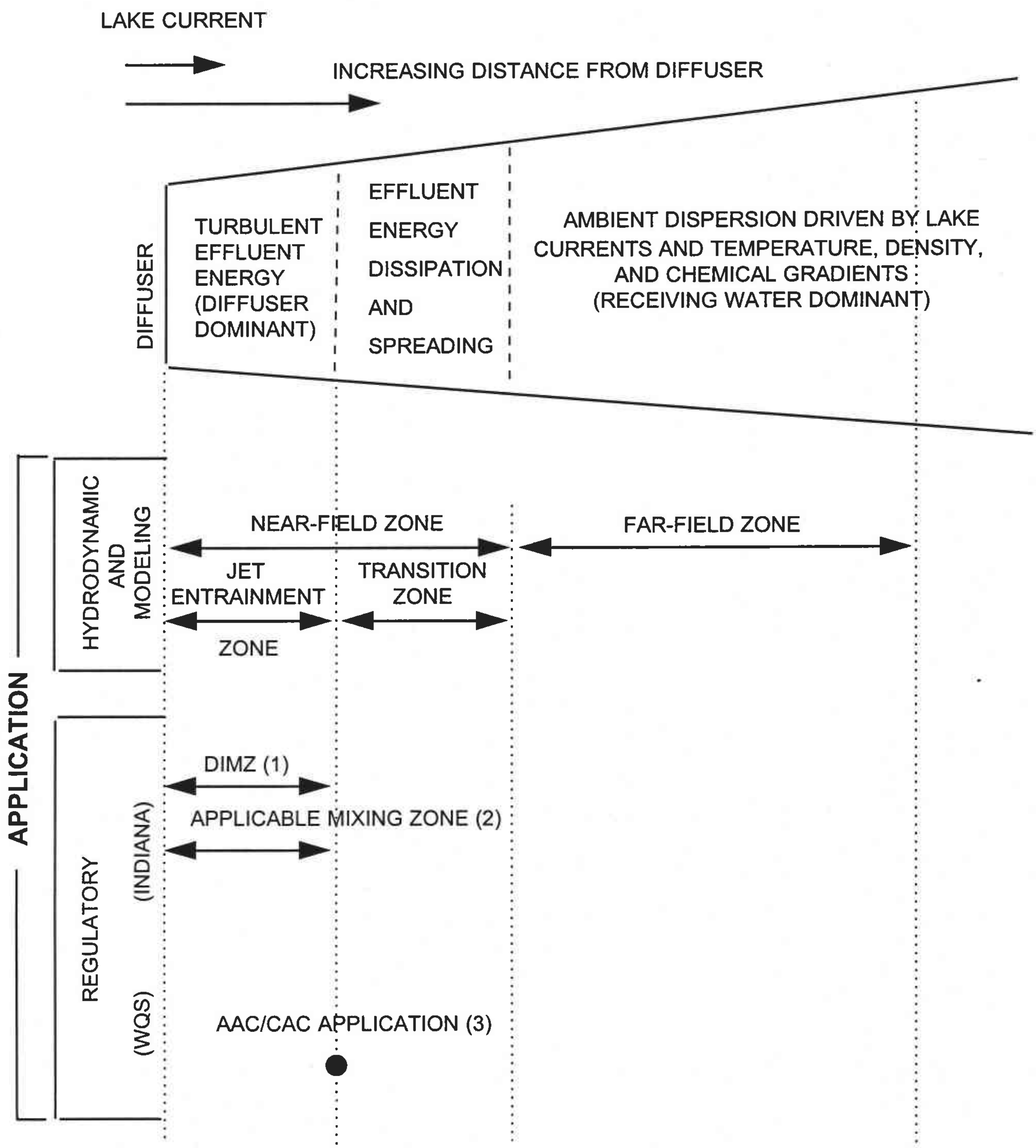


TABLE 1-3. MIXING ZONE TERMINOLOGY (continued)

FOOTNOTES	ABBREVIATION	DEFINITION
(1)	DIMZ	Discharge-Induced Mixing Zone: Concentrations of toxic substances shall not exceed the CMC outside the zone of initial dilution ... unless an alternate mixing zone demonstration is conducted and approved in accordance with 327 IAC 5-2-11.4(b)(4), in which case, the CMC shall be met outside the discharge-induced mixing zone ... (327 IAC 2-1.5-8(b)(1)(E)(i)). In no case shall a mixing zone for a discharge into the open waters of Lake Michigan be granted that exceeds the area where discharge-induced mixing occurs. (327 IAC5-2-11.4(b)(4)(C)).
(2)	MZ	Mixing Zone: An area contiguous to a discharge where the discharged wastewater mixes with the receiving waters. Where the quality of the effluent is lower than that of the receiving waters, it may not be possible to attain within the mixing zone all beneficial uses which are attained outside the zone. The mixing zone should not be considered a place where effluents are treated. (327 IAC 2-1.5-2(55)). In addition, this is equivalent to the designated mixing zone and the approved mixing volume. (327 IAC 5-2-11.3(b)(1)(C)(iii)(HH) and 5-2-11.7(c)(4)). At all times, all waters outside of the applicable mixing zones determined in accordance with 327 IAC 5-2-11.4(c) through (f) shall be free of substances in concentrations ... chronically toxic to, or be carcinogenic, mutagenic, or teratogenic to humans, animals, aquatic life, or plants. (327 IAC 2-1.5-8(b)(2)). For discharges into the open waters of Lake Michigan, ... for allocations based on acute aquatic life criteria of values, the CMC shall not be exceeded ... , unless a mixing zone demonstration is conducted and approved under subdivision (4), in which case the CMC shall be met outside the alternative mixing zone. (327 IAC 5-2-11.4(b)(2)(A)(i)). ... chronic criteria or value shall not be exceeded ... unless an alternative mixing zone is demonstrated ... (327 IAC5-2-11.4(b)(2)(A)(ii)). Historical Footnote: In the March 23, 1995 federal GLI, USEPA used the term "alternate mixing zone" to differentiate a demonstrated mixing zone using site information from a 10:1 default dilution. Indiana adopted this terminology but eliminated the default dilution in its regulations when implementing the GLI.
(3)	AAC	Acute Aquatic Criteria: Receiving water application point. (327 IAC 5-2-11.4(b)(2)(i)(AA)).
	CAC	Criterion Aquatic Concentration: Receiving water application point. (327 IAC 5-2-11.4(b)(2)(ii)(AA)).
	AAC/CAC	For a discharge with an approved alternate mixing zone, acute and chronic wasteload allocations are calculated using the same mixing ratio. (327 IAC 5-2-11.4(c)(4)(B) and (5)).

TABLE 1-4. INDIANA WATER QUALITY CRITERIA

Parameter	Acute Aquatic Life CMC, total (µg/L)	Chronic Aquatic Life CCC, total (µg/L)	Human Health Noncancer Drinking (µg/L)	Human Health Noncancer Nondrinking (µg/L)	Background Concentration (b) (µg/L)
Tier I (a)					
Ammonia-N Summer	3,600	820			2.7
Ammonia-N Winter	6,940	1,580			2.7
Arsenic (III), Total **(c)**	339.8	147.9			0.84
Chlorides	860,000	230,000			12,640
Chromium (VI), Total	16.02	10.98	134	14,000	0
Chromium (III), Total **(d)(e)**	2,402.88	114.85	410,000	43,000,000	0
Copper, Total **(e)(g)**	19.48	12.59	280	56,000	22.13
Cyanide, Free **(f)**	22				0.3
Cyanide, Total			600	48,000	0.3
Fluoride	11,000	1,000			127
Iron, Dissolved		300			41.3
Nickel, Total **(e)**	631.20	70.18	460	42,000	0.14
Selenium, Total		5.00			0.05
Sulfates		250,000			25,866
Total Dissolved Solids		750,000			167,270
Zinc, Total **(e)**	161.27	161.27	9,000	246,000	5.27

Notes:

(a) Tier I criteria presented for compounds detected or believed present in Outfall 001 (except As (III), which is not detected in Outfall 001).
(b) Background concentration = Whiting Intake Jan 1992 to Dec 1995 calculated as per 327 IAC (5-2-11.4(a)(8)).
(c) Assume Arsenic (III) background is equal to value from arsenic, total database .
(d) Assume Chromium (III) background is equal to value from chromium, total database.
(e) Chromium (III), Copper, Nickel, and Zinc are Hardness dependent (Hardness = 142 mg/L).
(f) Assume Cyanide, free background is equal to value from cyanide, total database.
(g) Background database is for both total and dissolved copper is under evalutation by IDEM due to concerns with current database validity.

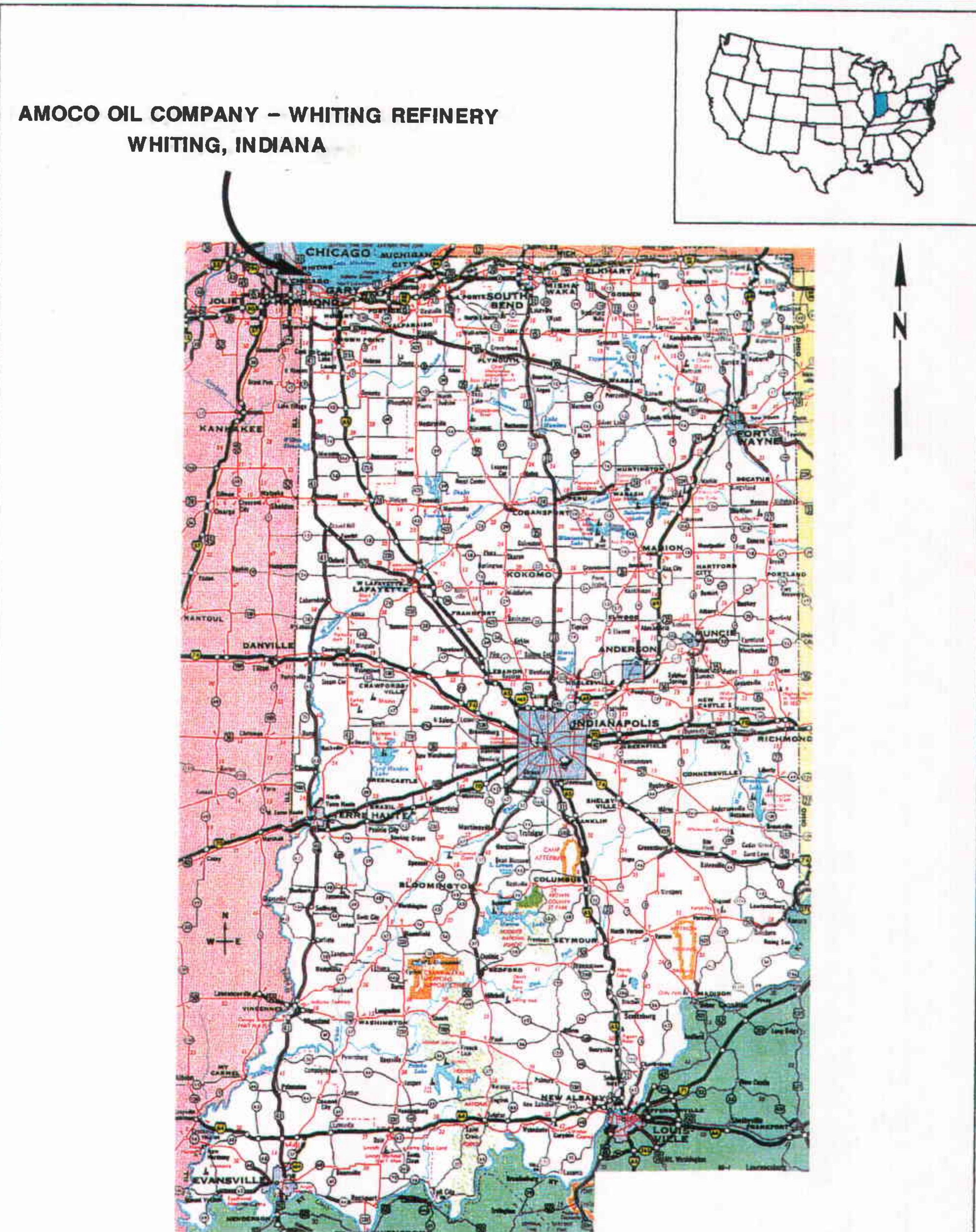
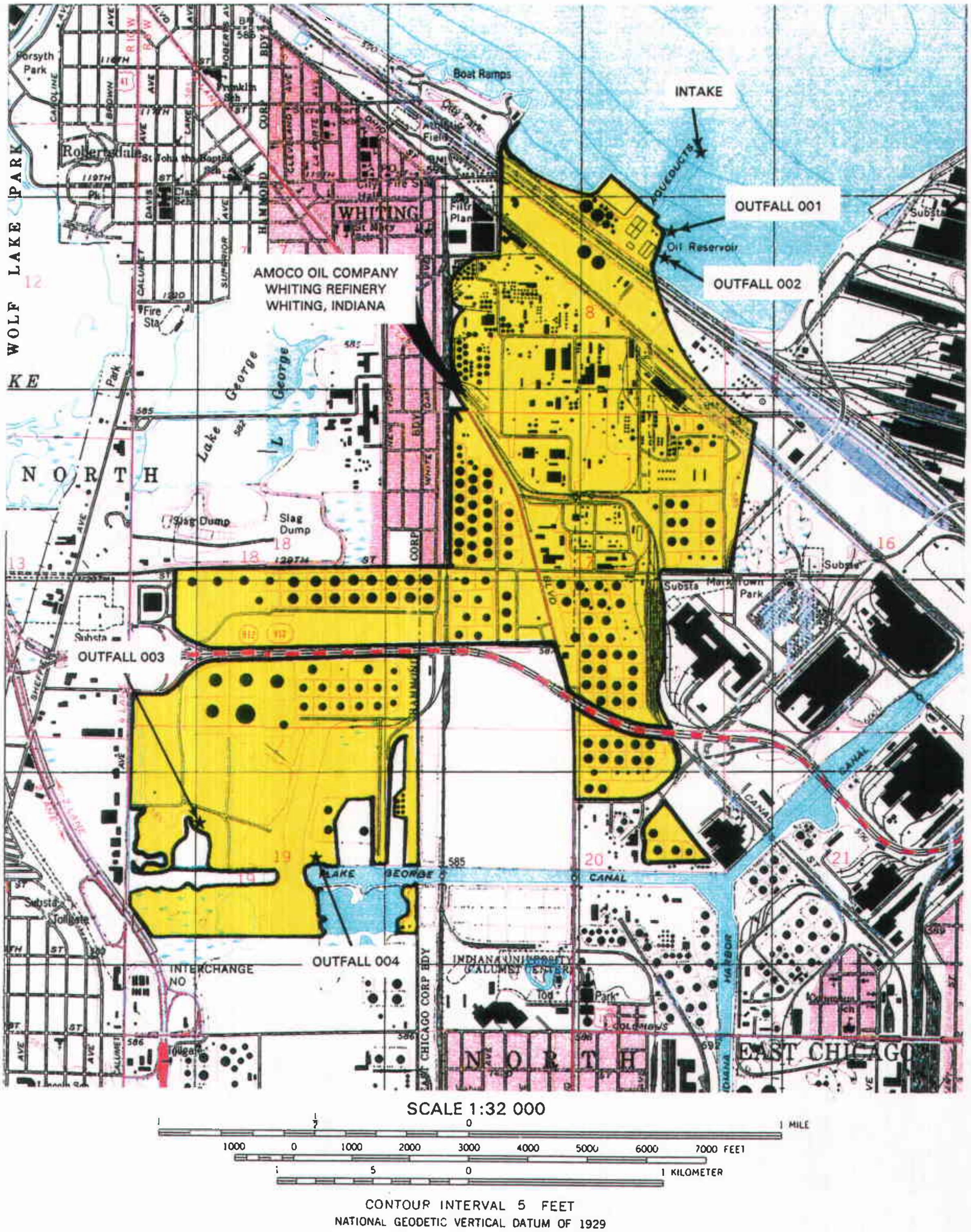


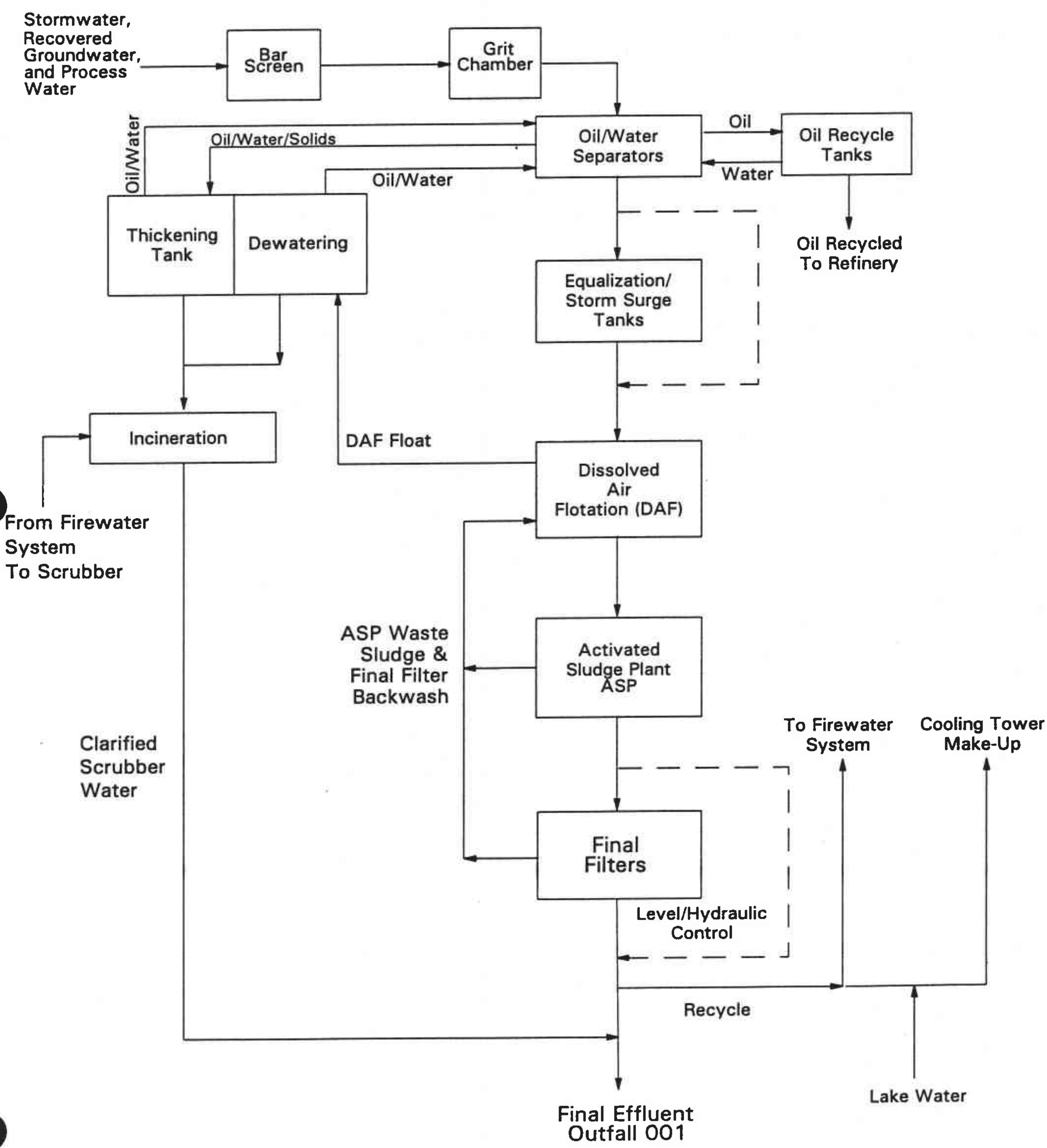
FIGURE 1-1
LOCATION MAP
WHITING, INDIANA

FIGURE 1-2
AREA MAP
AMOCO OIL COMPANY - WHITING REFINERY



SOURCE: USGS 7.5 min. TOPOGRAPHIC MAPS LAKE CALUMET ILL. AND WHITING, IND. 1991

FIGURE 1-3
WASTEWATER TREATMENT PLANT - WATER FLOW DIAGRAM
AMOCO OIL COMPANY - WHITING REFINERY



3148\94PERMIT\FIG1-3.DRW

AUGUST 1994

SECTION 2

SECTION 2.0
MIXING ZONE DISPERSION ANALYSIS

Amoco proposes to install a multiport diffuser for the discharge of treated effluent from Outfall 001. Though it is not necessary to satisfy Indiana mixing zone demonstration requirements, the use of a multiport diffuser provides an additional amount of environmental protection by ensuring more rapid and immediate mixing than is provided by the existing outfall.

2.1 MULTIPORT DIFFUSER MODELING

Amoco has evaluated a proposed diffuser location (Site S3500) in Lake Michigan as shown in Figure 2-1. The rationale for this site is to maximize mixing with ambient waters by locating the diffuser in deeper waters where more water volume is available for rapid mixing than is available at the current Outfall 001. Site S3500 is located in Lake Michigan approximately 3,500 ft from the current Outfall 001 in water depths measured at 28 to 30 ft. Specific benefits of a multiport diffuser at this location include:

1) The diffuser, by design, provides even more rapid and immediate mixing in a small area.
2) The diffuser would be located offshore, thereby minimizing plume contact with Lake Michigan shoreline.
3) The diffuser site would be exposed to the general nearshore current/circulation patterns that enhance local mixing.
4) The discharge would be present in deeper waters completely submerged and surrounded by lake water available for entrainment (induced mixing). Vertical mixing throughout the water column would be achieved as the positively buoyant plume rises toward the surface.

In order to evaluate the dispersion and size of a mixing zone from a multiport diffuser, the USEPA-endorsed computer model CORMIX, developed by Dr. Gerhard Jirka at Cornell University, was used for analysis. Specifically, the CORMIX2 expert system was utilized to determine achievable dispersion at the edge of the Jet Entrainment Zone, the Near-

Field Zone, and the Far-Field Zone. CORMIX2 calculates plume characteristics (i.e., dispersion, plume width) for specific regions (modules) of the mixing zone which are defined by discharge and ambient water classification criteria. The specific regions are linked together by transition equations resulting in a complete projection of the plume up to a user-specified distance. Although several computer models are listed in the USEPA 1991 TSD, CORMIX2 has been commonly used by regulators as a useful analysis tool for NPDES permitting. CORMIX2 was also selected because it integrates both near-field and far-field projections with customized transition equations. The CORMIX2 model also features additional sensitivity to receiving water boundaries. CORMIX2 provided the model estimates given in the remainder of this report. As noted in Attachment 1, computer models usually underestimate achievable dispersion. This overestimate of exposure leads to a conservative estimate of the evaluation of risk impact.

2.1.1 Model Input Parameters and Diffuser Design

The main criterion for development of an effective diffuser design is to maintain a specific port exit velocity at the average effluent flowrate. The USEPA 1991 TSD recommends maintaining a 10 ft/sec port exit velocity to ensure rapid mixing. If the effluent flow rate and exit velocity are known, the port diameter can be determined for a selected number of diffuser ports. Table 2-1 presents various configurations for a diffuser discharging the average Outfall 001 flowrate of 13 mgd. For this analysis, a 90-ft diffuser (approximate length) with ten 6-in diameter ports spaced 10 ft apart was chosen as an appropriate design for the Amoco discharge (see Attachment 2). The diffuser is unidirectional with all 10 ports pointing toward the center of the lake (due north, away from shore). The 6-in diameter ports and 10-ft port spacing provide standard dimensions for ease of installation and still maintain a 10 ft/sec exit velocity (actually calculated as 10.3 ft/sec). Other configurations could be used for final design; however, port diameters should not be too small where clogging from debris might occur and spacing should be large enough where immediate entrainment of adjacent ports is avoided. Modeling results for various diffuser designs (Table 2-1) revealed slight differences in jet entrainment zone dispersion for alternate design configurations, yet were within the relative range of accuracy of the model of the 10 port design.

Table 2-2 presents the remaining input parameters for the CORMIX2 simulations. Bathymetry measurements taken May 11, 1994 verified that Site S3500 is located at a lake depth of 28.5 ft. Long-term average effluent and lake temperatures revealed an annual average temperature difference of 17 °C. The effluent plume is usually warmer than the receiving water and a temperature difference of 20 °C was used in the model. Field measurements of lake temperature and conductivity taken during the long term bioassessment program (1994 to 1997), as shown in Table 2-3, revealed no significant temperature or conductivity gradients (i.e., no thermal stratification) in the Lake Michigan at the S3500 location. Furthermore, field measurements of conductivity confirmed that differences between the effluent and lake were negligible with respect to density in fresh water. Therefore plume buoyancy is driven solely by temperature differences. The positively buoyant condition (effluent temperature greater than receiving water temperature by 20 °C) resulted in the use of a 0 degree (horizontal) port discharge angle, where the plume rises to the surface and is exposed to the full vertical water column.

Lake velocity (current) in nearshore Lake Michigan is influenced by several forces (primarily wind) and changes in both speed and direction. Ambient velocity is a significant mixing force, especially in the far-field zone, as increased lake velocity will increase plume dispersion. Localized wind currents and along-shore physical features create a continuously dynamic condition in the lake. For the location of S3500, wind currents provide the predominant transport mechanism. Based on Midway Airport meteorological data compiled by NOAA (Attachment 3), the prevailing wind direction for the south end of Lake Michigan is out of the south at an average speed of around 10 knots. A general engineering rule for estimating lake currents generated by surface wind is to multiply the wind speed by one-thirtieth (1/30) to obtain the wind-induced lake velocity. Therefore, this would result in an average lake velocity of around 0.18 m/sec (0.59 ft/sec). A summary of measured nearshore Lake Michigan currents, primarily for Argonne National Laboratory studies conducted in the Calumet area, is presented in Table 2-4. For purposes of this analysis, a condition representing conservative lake velocity (0.10 m/sec) was used. The 0.10 m/sec lake velocity is less than velocity values derived from prevailing wind data and is consistent with the range of actual measured values.

2.1.2 Model Results

For the input parameters described above, model runs were conducted for dispersion estimation as a function of distance from the diffuser at S3500. The model output is given in Attachment 4 and graphically presented in Figure 2-2. At S3500, the plume is projected to be fully vertically mixed in the jet entrainment zone (per CORMIX2 classification) and extends to a distance of one-half of the diffuser length (45 to 50 ft). The one-half to one diffuser length distance provides a conservative guide for establishing the extent of the jet entrainment zone, or the Discharge-Induced Mixing Zone (DIMZ) (1980 Lee and Jirka). The dispersion projected at this distance is 54:1 for S3500. As discussed in Section 1, the USEPA's 1991 TSD states that if the travel time through the acute mixing zone (DIMZ) is less than 15 minutes, then the AAC (based on one-hour exposure) is not exceeded. CORMIX2 projects a time of plume travel of less than 90 seconds to reach the edge of the DIMZ (45 to 50 ft).

After the jet entrainment zone, the CORMIX2 model projects a transition zone that is "insignificant in spatial extent and will be bypassed" (see CORMIX Model output, Attachment 4). Therefore, there is no additional dispersion gained in the transition zone and the extent of the Near-Field Zone is equal to the extent of the DIMZ. At the DIMZ, the extent of discharge-induced mixing is equal to 45 to 50 ft from the diffuser where a dispersion of 54:1 is achieved. Since Indiana law limits the mixing zone to the DIMZ for a Lake Michigan discharger, Amoco proposes a mixing zone of 50 feet around the diffuser structure.

Past the Near-Field Zone, physical mixing continues, and CORMIX2 dispersion projects into the Far-Field Zone up to a user-specified distance of 3,300 ft. The actual extent of the Far-Field Zone, used for regulatory application is determined from regulatory definitions, not from hydrodynamic principles since the plume will continue to disperse at the molecular level over great distances. The 1991 TSD suggests that the DIMZ occupy 10 percent of the far-field zone, therefore, an appropriate far-field distance of 500 ft can be established for the Amoco diffuser. At this distance, CORMIX2 projects an effluent dispersion of 77:1 for the far-field zone. A total mixing zone of 500 feet radius around the diffuser structure is consistent with USEPA approaches to protecting the environment.

2.2 SUMMARY

The mixing zone dispersion analysis for a multiport diffuser located at S3500, conducted in accordance with USEPA guidance, shows that the proposed discharge configuration adds a margin of safety to protect the quality of the receiving waters compared to the existing outfall structure. This enhanced environmental protection is due to the rapid and immediate mixing that occurs within a small area as a result of the diffuser.

TABLE 2-1. PORT SIZES AND SPACING FOR A 90-FT MULTIPORT DIFFUSER

NUMBER OF PORTS	EFFLUENT FLOW (mgd)	EFFLUENT FLOW (cfs)	EXIT VELOCITY (ft/sec)	PORT AREA (sq ft)	PORT DIAMETER (in)	DIFFUSER PORT SPACING (ft)
1	13.0	20.1	10	2.01	19.2	
2	13.0	20.1	10	1.01	13.6	90.0
3	13.0	20.1	10	0.67	11.1	45.0
4	13.0	20.1	10	0.50	9.6	30.0
5	13.0	20.1	10	0.40	8.6	22.5
6	13.0	20.1	10	0.34	7.8	18.0
7	13.0	20.1	10	0.29	7.3	15.0
8	13.0	20.1	10	0.25	6.8	12.9
9	13.0	20.1	10	0.22	6.4	11.3
10	13.0	20.1	10	0.20	6.1	10.0
11	13.0	20.1	10	0.18	5.8	9.0
12	13.0	20.1	10	0.17	5.5	8.2
13	13.0	20.1	10	0.15	5.3	7.5
14	13.0	20.1	10	0.14	5.1	6.9
15	13.0	20.1	10	0.13	5.0	6.4

Note:
10-port diffuser selection based on design experience.

TABLE 2-2. CORMIX2 MODEL INPUT PARAMETERS

PARAMETER	VALUE	RATIONALE
Effluent flow	13 mgd	Long term average
Port exit velocity	10.3 ft/sec	EPA TSD recommendation
Number of ports	10	Standard design (Table 2-1)
Port diameter	6 in	Standard design (Table 2-1)
Diffuser length	90 ft	Standard design (Table 2-1)
Port spacing	10 ft	Standard design (Table 2-1)
Port discharge angle	0 degrees	Optimizes plume buoyancy
Diffuser height off bottom	1.6 ft (0.5 m)	Practical estimate
Effluent temperature	30 °C	Long term average = 28 °C
Lake temperature	10 °C	Long term average = 11 °C
Temperture difference	20 °C	Conservative input (average = 17ºC)
Minimal lake velocity	0.33 ft/sec (0.10 m/sec)	Conservative input (average = 0.59 ft/sec)

In each case, selection of each parameter value was made to result in smaller dispersion values than would have been calculated with average values. The aggregate result is that the dispersion in Lake Michigan is underestimated herein.

TABLE 2-3. LAKE MICHIGAN WATER QUALITY DATA

Temperature (°C)															
Date	5/10/94	5/23/95	5/24/95	5/25/95	5/23/95	5/24/95	5/25/95	6/5/96	10/21/96	10/24/96	10/21/96	10/22/96	4/28/97	4/28/97	4/29/97
Location	S3500	C3501	C3501	C3501	S3500	S3500	S3500	S3500	C3501	C3501	S3500	S3500	C3501	S3500	S3500
Depth (ft)															
surface	11.87	13.3	13.3	13.7	14	13.3	13.5	15	14.8	13.6	14.7	15.1	9.7	10.7	8.5
2 to 3				13.7	14			15	14.8	13.6	14.7	15.1	9.7	10.7	8.5
5 to 6	11.87	13.3	13.3	13.7	13.3	13.3	13.5	15	14.8	13.6	14.7	15	9.1	10.7	8.5
8 to 9	11.85			13.7	13.2		13.5	14	14.6	13.6	14.7	14.7	8.4	8.9	8.5
11 to 12	11.86	13.3	13.3	13.7	13	13.3	13.5	14	14.5	13.6	14.4	14.5	8.2	8.4	8.4
14 to 15	11.84	13.3	13.3	13.7	13	13.3	13.5	14	14.5	13.6	14.4	14.3	8	8.2	8.4
17 to 18	11.86			13.7	13		13.5	14	14.4	13.6	14.4	14.2	7.9	8.1	8.3
20 to 21	11.84	13.3	13.3	13.7	12.7	13.3	13.5	14	14.4	13.6	14.4	14.2	7.9	8	8.3
24 to 25	11.85			13.7	12.5		13.5	13	14.4	13.6	14.3	14.2	7.8	7.9	8.3
27 to 28		13.3	13.3	13.7	12.2	13.3	13.5	13	14.4	13.6	14.4	14.2	7.9	7.8	8.3

Conductivity (µmhos/cm)															
Date	5/10/94	5/23/95	5/24/95	5/25/95	5/23/95	5/24/95	5/25/95	6/5/96	10/21/96	10/24/96	10/21/96	10/22/96	4/28/97	4/28/97	4/29/97
Location	S3500	C3501	C3501	C3501	S3500	S3500	S3500	S3500	C3501	C3501	S3500	S3500	C3501	S3500	S3500
Depth (ft)															
surface	285	301	295	298	301	291	289	300	308	294	306	299	313	318	291
2 to 3				290	299			301	308	294	309	298	313	317	286
5 to 6	285	296	292	290	296	298	289	304	308	291	305	298	311	315	287
8 to 9	285			291	296		290	297	306	294	305	297	303	306	291
11 to 12	285	289	289	292	295	301	290	305	305	298	301	294	303	303	290
14 to 15	285	305	293	291	296	300	292	300	305	294	304	292	301	304	290
17 to 18	285			294	297		289	300	304	294	301	289	301	303	278
20 to 21	285	300	301	293	296	297	296	300	300	288	302	289	300	300	290
24 to 25	284			293	294		294	300	300	289	300	289	300	298	294
27 to 28		306	301	292	294	297	280	302	300	294	300	289	300	298	297

TABLE 2-4. SUMMARY OF LAKE MICHIGAN CURRENT MEASUREMENTS

REFERENCE	DATE	FREQUENCY	NUMBER OF CURRENT METERS	CURRENT METER LOCATION	DEPTH	RESULT
Snow 1974	Nov. 8 to Dec. 8, 1973	20 min	3	At 68th St. Crib (1) Off Inland landfill (2)	5.2m (1) 3m and 6m (2)	Typical lake currents on the order of 0.05 to 0.15 m/sec
Saunders 1976	June 23 to Dec. 22, 1975	Continuous	5	3 km offshore from South Water Filtration Plant (SWFP)	12 m (mid-depth)	Strong currents observed for Nov. 17 to Dec. 22 Speed range = 0.15 to 0.30 m/sec Maximum speed = 1.0 m/sec
McCown 1976	Feb. 11 to Feb. 17, 1976	40 min	3	3 km offshore from SWFP	1m off bottom	Maximum speed observed was 0.15 m/sec
Harrison 1977 McCown 1978	Jan. 4 to Mar. 26, 1977	8 min	4	3 km offshore between Indiana Harbor Ship Canal (IHSC) and SWFP	1.5 m off bottom	Average speed = 0.015m/sec Root-mean-square speed = 0.074 m/sec Maximum speed = 0.15 m/sec Significant ice cover present late Jan-early Feb.

REFERENCES

Snow, October 1974, "Water Pollution Investigation: Calumet Area of Lake Michigan. Volume 1", IIT Research Institute.

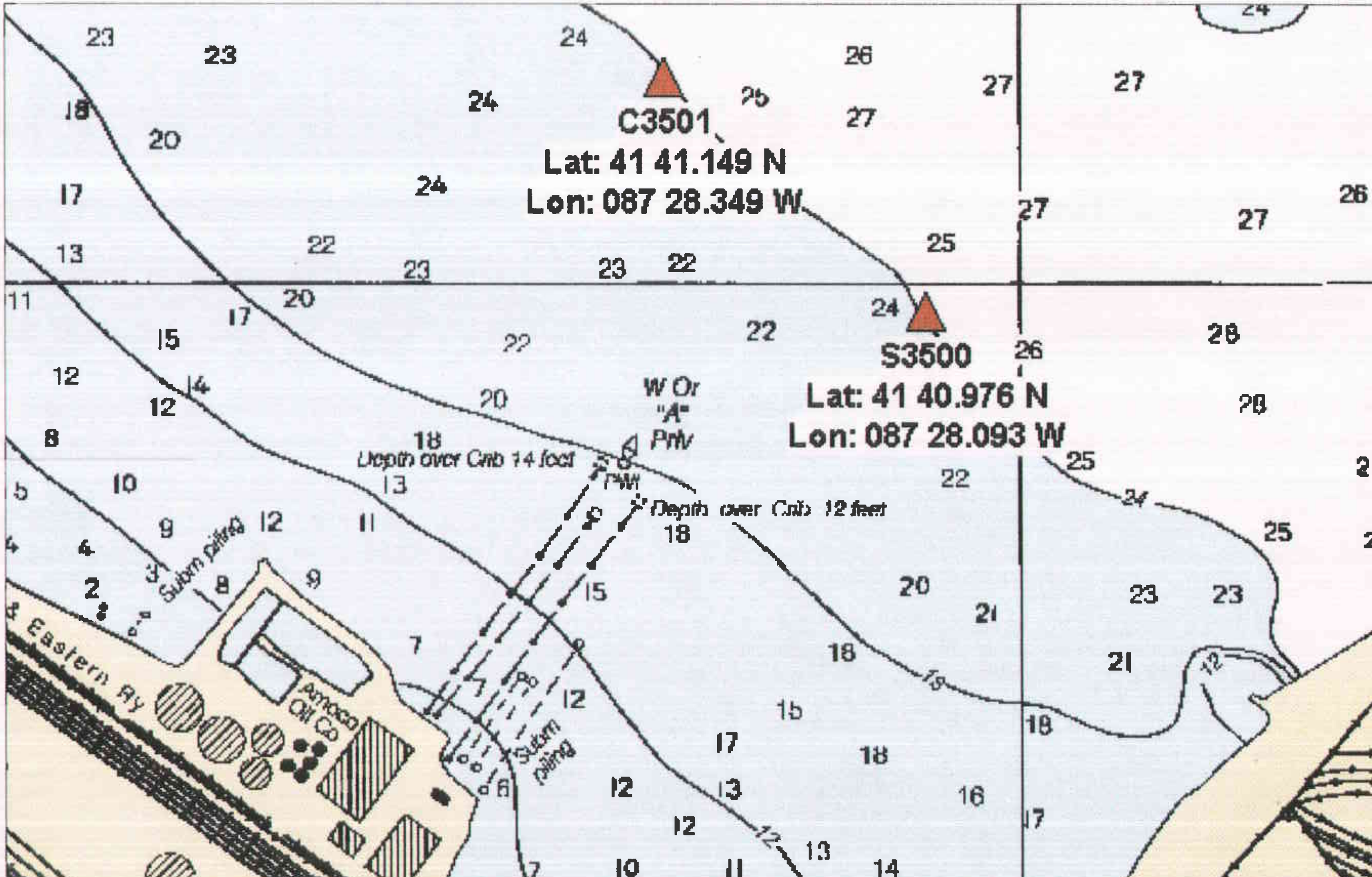
Saunders, et al., May 1976, "Nearshore Currents and Water Temperatures in Southwestern Lake Michigan (June - December, 1975)", Argonne National Laboratory (ANL).

McCown, et al., July 1976, "Transport and Dispersion of Oil Refinery Wastes in the Coastal Waters of Southwestern Lake Michigan (Experimental Design - Sinking Plume Condition)", ANL.

Harrison, et al, December 1977 "Pollution of Coastal Waters off Chicago by Sinking Plumes from the Indiana Harbor Canal", ANL.

McCown, et al., November 1978, "Transport of Oily Pollutants in the Coastal Waters of Lake Michigan", ANL.

Figure 2-1
Water Depth at the Proposed Diffuser Location (S3500)



From: Calumet and Indiana Harbors NOAA Chart 14929

Nautical Miles
0.00 0.10 0.20

FIGURE 2-2. CORMIX2 RESULTS FOR MULTIPORT DIFFUSER

SECTION 3

SECTION 3.0
MIXING ZONE DEMONSTRATION

3.1 INTRODUCTION

To grant a mixing zone, the permittee must provide specific information to assure that a mixing zone is appropriate for the discharge. The necessary information for a mixing zone demonstration has been described by USEPA guidance and Indiana state rules to determine the boundaries of the mixing zone, the magnitude of mixing, the impact of the mixing zone on the receiving water, and the steps taken to prevent acute impacts to aquatic life and prevent impairment of the use of the water as follows:

- 327 IAC 5-2-11.4(b)(4)(A)(i) - Document the characteristics and location of the outfall structure, including whether technologically enhanced mixing will be utilized.
- 327 IAC 5-2-11.4(b)(4)(A)(ii) - Document the amount of dilution occurring at the boundaries of the proposed mixing zone and the size, shape and location of the area of mixing, including the manner in which diffusion and dispersion occur.
- 327 IAC 5-2-11.4(b)(4)(A)(iii) - For sources discharging to the open waters of Lake Michigan, define the location at which discharge-induced mixing ceases.
- 327 IAC 5-2-11.4(b)(4)(A)(iv) - Document the physical including substrate character and geomorphology, chemical and biological characteristics of the receiving waterbody, including whether the receiving waterbody supports indigenous, endemic or naturally occurring species.
- 327 IAC 5-2-11.4(b)(4)(A)(v) - Document the physical, chemical, and biological characteristics of the effluent.
- 327 IAC 5-2-11.4(b)(4)(A)(vi) - Document the synergistic effects of overlapping mixing zones or the aggregate effects of adjacent mixing zones.
- 327 IAC 5-2-11.4(b)(4)(A)(vii) - Show whether organisms would be attracted to the area of mixing as a result of the effluent character.

- 327 IAC 5-2-11.4(b)(4)(B)(i) - The mixing zone would not interfere with or block passage of fish or aquatic life.

- 327 IAC 5-2-11.4(b)(4)(B)(ii) - The level of pollutant permitted in the waterbody would not likely jeopardize the continued existence of any endangered or threatened species listed under Section 4 of the ESA or result in the destruction or adverse modification of such species habitat.

- 327 IAC 5-2-11.4(b)(4)(B)(iii) - The mixing would not extend to drinking water intakes.

- 327 IAC 5-2-11.4(b)(4)(B)(iv) - The mixing zone would not impair of otherwise interfere with the designated uses of the receiving water or downstream waters.

- 327 IAC 5-2-11.4(b)(4)(B)(v) - The mixing zone would not promote undesirable aquatic life or result in a dominance of nuisance species.

- 327 IAC 5-2-11.4(b)(4)(B)(vi) - By allowing the additional mixing: (AA) substances will not settle to form objectionable deposits; (BB) floating debris, oil, scum, and other matter in concentrations that form nuisances will not be produced; and (CC) objectionable color, odor, taste, or turbidity will not be produced.

- 327 IAC 5-2-11.4(b)(4)(C) - In no case shall a mixing zone for a discharge into the open waters of Lake Michigan be granted that exceeds the area where discharge-induced mixing occurs.

This information is evaluated to assure that it is environmentally protective to use a mixing zone for the discharge and to define the point of application of receiving water quality standards. Also, to assist the Commissioner regarding additional information for assessing the mixing zone (based on aquatic life, human health, or wildlife), data and references are presented in Volume II (submitted August 1994) and in this revised volume.

Amoco proposes that a mixing zone be included in its renewed NPDES permit. The following discussion describes the physical, chemical, and biological characteristics of the receiving water (southern Lake Michigan). It also describes the Amoco Outfall 001 discharge at the proposed diffuser site. These characteristics are analyzed in the context of the specific points noted in Indiana 327 IAC 5-2-11.4(b)(4) to demonstrate that an appropriate mixing zone can be delineated in southern Lake Michigan consistent with Indiana rules and USEPA guidelines (1993 WQSH - Chpt 5, 1991 TSD - Chpt 2 & 4).

3.2 INDIANA MIXING ZONE REGULATORY REQUIREMENTS (327 IAC 5-2-11.4(b)(4))

As discussed in Attachment 1, the USEPA provides guidance on determining and assessing the applicability of mixing zone implementation for a discharge. As shown in Table A1-1, these USEPA specifications are incorporated into the Indiana Water Quality Standards. The following text presents the Indiana mixing zone demonstration regulatory language and Amoco's responses to the requirements.

<u>327 IAC 5-2-11.4(b)(4)(A)(i) - Document the characteristics and location of the outfall structure, including whether technologically enhanced mixing will be utilized.</u>

Technologically enhanced mixing will be provided by the use of a state-of-the-art high-rate multiport diffuser. A high-rate diffuser maximizes mixing and minimizes organism exposure time. The preliminary design of this diffuser (Attachment 2) includes the following characteristics:

- header length = 90 ft
- number of ports = 10
- port spacing = 10 ft
- port diameter = 6 in
- diffuser orientation = unidirectional with ports pointing due north (away from the shore toward the center of the lake)
- vertical port discharge angle = 0 degrees from horizontal
- diffuser height off lake bottom = 1.6 ft

The diffuser will be located about 3,500 ft northeast of the current Outfall 001 at latitude 87° 28.093'W and longitude 41° 40.976'N. These coordinates correspond to Station S3500 of the current long-term bioassessment program.

<u>327 IAC 5-2-11.4(b)(4)(A)(ii) - Document the amount of dilution occurring at the boundaries of the proposed mixing zone and the size, shape and location of the area of mixing, including the manner in which diffusion and dispersion occur.</u>

The dilution (dispersion) ratio has been optimized by modeling a high-rate submerged multiport diffuser located approximately 3,500 ft from the current Outfall 001. Dispersion estimates were derived from the USEPA-supported model CORMIX2 as discussed in detail in Section 2. Using conservative model input parameters, including plume buoyancy and lake velocity, CORMIX2 projected a DIMZ dispersion of 54:1 at a distance of one-half diffuser length (45 to 50 ft) from the diffuser. The CORMIX2 DIMZ is hydraulically equivalent to the extent of the Near-Field Zone. Far-Field projections indicated an appropriate dispersion of 77:1 achieved at a distance of 500 ft from the diffuser.

As mentioned previously, since the Outfall 001 diffuser will be a discharge to the open waters of Lake Michigan, the applicable mixing zone dispersion is capped, as per 5-2-11.4(b)(4)(C), at the point where discharged induced mixing ceases. Therefore, the applicable mixing zone dispersion and distance are reduced to the corresponding CORMIX2 DIMZ values (54:1 and 50 ft, respectively). The applicable mixing zone would directly utilize a 54:1 dispersion for calculating both acute and chronic wasteload allocation values as presented in 327 IAC 5-2-11.4(c).

Amoco proposes delineating a mixing zone that maintains a 50-ft distance from all points on the diffuser. One can envision the mixing zone plan-view shape as a "racetrack" surrounding the 90-ft-long diffuser; one 100 ft x 90 ft rectangle centered over the diffuser length and one semi-circle area (radius = 50 ft) at each end. For the mixing zone, the vertical profile would occupy the entire average water depth (28 ft) within this area. A mixing zone that completely surrounds the diffuser is necessary to accommodate lake velocities induced by winds of various directions. The mixing zone shape described above corresponds to lateral area of 0.39 acre. A conceptual sketch of the mixing zone is given in Figure 3-1.

The mixing zone area would be located about 3,500 ft northeast of the current Outfall 001 at longitude 87° 28.093'W and latitude 41° 40.976'N as shown in Figure 3-2. The mixing zone would not overlap any adjacent mixing zones or outfalls. Furthermore, the mixing zone will not contact any shorelines or other receiving waters since they are greater than 50 ft away from the diffuser.

The manner in which diffusion and dispersion will occur is through rapid and immediate mixing of discharged effluent with Lake Michigan receiving water. The diffuser is designed to maintain the USEPA-recommended discharge exit velocity of 10 ft/sec at average effluent flowrate (i.e., 13 mgd). This discharge velocity (in excess of ambient velocity) entrains surrounding Lake Michigan water to effectively mix the effluent within a turbulent local environment.

<u>327 IAC 5-2-11.4(b)(4)(A)(iii) - For sources discharging to the open waters of Lake Michigan, define the location at which discharge-induced mixing ceases.</u>

The diffuser will be located in the open waters of Lake Michigan. Discharge-induced mixing ceases at the edge of the CORMIX2 DIMZ, which is equivalent to the edge of the Near-Field Zone where plume velocity approaches ambient lake velocity. For the model application chosen to simulate initial mixing, plume velocity was not given as a function of distance from the diffuser. However, based on the research references used to develop the model equations, the length of the DIMZ can be defined as one-half to one diffuser length downstream from the diffuser. For the 90-ft diffuser, this corresponds to a DIMZ distance of 45 to 90 ft. Amoco proposes a DIMZ distance of 50 ft as a conservative value consistent with the appropriate means to delineate a mixing zone.

In practice, the exact location where discharge-induced mixing ceases will depend on the magnitude and direction of the wind-induced lake velocity. To accommodate all potential lake current directions a mixing zone that surrounds the entire diffuser is proposed. For this mixing zone, this corresponds to a 0.39 acre area shaped like a "racetrack" that is 50 ft from all points from the diffuser (see Figure 3-1).

327 IAC 5-2-11.4(b)(4)(A)(iv) - Document the physical including substrate character and geomorphology, chemical and biological characteristics of the receiving waterbody, including whether the receiving waterbody supports indigenous, endemic or naturally occurring species.

Information about the southern part of Lake Michigan has been published in numerous studies. Attachment 5 is a bibliography of technical documents relevant to this part of the lake. From a limnological basis, the deeper waters of Lake Michigan (typically termed "open waters" by limnologists) begin about 5 miles offshore in the southern part of the lake and respond to several physical forces (i.e., wind, thermal convection) which, in turn, affect the chemical and biological characteristics. Nearshore waters are most affected by local winds and shoreline and topographical features. These differences mean that the nearshore waters often have different physical, chemical, and biological characteristics than the deeper open waters. Studies within the nearshore zone, especially along the Indiana shore, likely provide more accurate information that may readily be extrapolated to the Amoco site.

Lake Michigan General Characteristics. Several studies have been conducted to characterize the circulation and transport of Lake Michigan waters. The causes and characteristics of Lake Michigan currents are dependent upon the location within the lake. Snow (1974) describes the primary causes of lake transport in the open (deep) waters (away from shore), such as wind forces, thermal convection, and Coriolis forces (rotation of the Earth). Other general lakewide influences include density gradients, weather patterns, and precipitation.

The open waters of Lake Michigan respond to general seasonal transport patterns. Thermal convection (vertical stratification) is a significant seasonal influence on general lakewide mixing and refers to the tendency of lakes to form distinct temperature layers. Stratification is typically observed in summer and winter. During summer, the surface waters, warmed by the sun, become less dense than the cooler, deeper waters. A boundary, known as a thermocline, separates the bottom waters from the surface waters. Algal photosynthesis in the upper, sunlit layer (the epilimnion) may alter the water chemistry, increasing dissolved oxygen levels, and decreasing the level of carbon dioxide and algal nutrients. Biological respiration and excretion below the thermocline (in the hypolimnion) tend to decrease dissolved oxygen levels and increase levels of carbon dioxide and nutrients. This stratification usually ends in autumn when the surface layer cools and the entire water column can more easily be mixed. During winter, another stratification may be established with the cooler waters on top of the lake and the warmer water below. This type of stratification ends in spring. An important feature of this stratification is the seasonal availability of nutrients, particularly in spring, which can encourage blooms of algae and their consumers, the zooplankton.

Lateral mixing of open waters results in observable lake currents. Baumgartner (1968), in conjunction with the Great Lakes Region of the Federal Water Pollution Control Administration (FWPCA), presented the results of field studies to define the general open water currents in Lake Michigan. The investigators found that currents do exist in the lake with complex interrelated flow patterns. Dr. Baumgartner testified: "[currents] vary in direction and magnitude from surface to depth, from length to width, and from side to side. The variability in time is significant on a seasonal basis, but important variabilities are also observed in shorter periods of time, such as days or even hours. Superimposed on the hourly variation is a continuous process of turbulent mixing of small parcels of water." Mortimer (1975) notes that the FWPCA report "does indeed present diagrams of average circulation for various seasons, depths, and wind regimes, but they are of little use for day-to-day prediction, because of overriding effects of short term fluctuations (internal waves and responses to local winds) and of the spatial complexity of these motions, particularly near shore."

Hence, in developing information for modeling dispersion of a discharge into the nearshore south end of Lake Michigan, there could be multiple influences on lake currents, of which one is wind induced. For a specific nearshore site (e.g., S3500), mixing dynamics could be more influenced by conditions near the area than the general lake-wide circulation. Thus in the CORMIX2 modeling, velocity data was reviewed specific to the area of the proposed diffuser to corroborate the use of wind-induced velocity as a transport mechanism at S3500.

To describe the biological characteristics of the receiving waters, Amoco implemented a Lake Michigan Biomonitoring Program in May 1994 within the area of the proposed diffuser to further evaluate limnological attributes of the nearshore zone and receiving water in support of Volume II of August 1994. Biomonitoring activities have continued since May 1994 up to and including April 1997. The Biomonitoring Program was designed to document the physical, chemical, and biological components of the receiving water, confirm the observations presented in Volume II (August 1994), and provide information to further characterize Lake Michigan at the proposed diffuser location. Key findings of the Biomonitoring Program that address 327 IAC 5-2-11.4(b)(4)(A)(iv) are presented below for the receiving water and supported by the Biomonitoring Program Database and Summary Report included as Attachment 6.

Nearshore Physical Characteristics. Nearshore lake currents, such as those encountered at the proposed Amoco diffuser site, are caused primarily by localized winds, with less influence from thermal convection or Coriolis forces. Vertical temperature stratification is seldom observable in the shallower depths and, if present at all, not maintained for long periods. As evident from direct measurements at the study sites, the temperature, pH, dissolved oxygen, and specific conductivity profiles are uniform over the 28-ft depth with no direct gradient influences expected. Coriolis forces require travel distances much larger than the delineated mixing zone to be of any consequence to overall transport.

Boundary effects due to shore and topographical features also dominate lake currents in the nearshore area. Nearshore currents will mainly follow the general direction of the wind and, in the instance of the wind blowing toward the shore, the lake water will deflect to follow the shoreline. Wind forces of sufficient duration induce ambient velocities throughout the water column in shallow lake areas, such as the beach zone near Amoco's existing Outfall 001 discharge thereby increasing the mixing.

Direct measurements of lake currents near the southwest Lake Michigan shoreline were made during tracer studies performed by Argonne National Lab in the 1970s. Saunders, et al. (ANL, "Nearshore Currents and Water Temperatures in Southwestern Lake Michigan (June - December, 1975)"), conducted continuous current measurements at five mooring stations located at mid-depth approximately five miles offshore of south Chicago. Currents in the region were predominately parallel to shore. As an example of typical results, the net motion of the water during November 17 to December 22, 1975 was toward the southeast, but at least 11 major current reversals occurred during this period. The average currents ranged from 0.15 to 0.30 m/sec with maximum observations of approximately 1.0 m/sec. Other current measurement studies are presented in Table 2-4.

Beach dune areas with gently sloping shores characterize the general lakeshore of the Indiana portion of Lake Michigan. Snow (1974) described the major substrate component of the nearshore Calumet area as comprised of sand. Bottom sediments can be resuspended from wave action and storms, as indicated by increased turbidity of nearshore waters during these events. Ayers (1967) also described the sediments of the southwestern corner of the lake to range from silty sand to till, with fine to coarse sands covering most of the area.

Amoco studies show that the substrate of Lake Michigan in the vicinity of the proposed diffuser is a flat plane of less than one percent slope that consists of 76 percent sand, 21 percent silt, and 2 percent clay. Gravel or larger sized particles are widely scattered and typically not encountered. Particle size distributions, presented in Attachment 6, reveal a mottled distribution of silty sand substrates ranging from 49 to 90 percent sand material. Divers have observed that the surface of the sand substrate exhibits surge (oscillation) ripples that are formed in response to wind direction and surface wavelength patterns. The oscillation ripples change in direction and form when bottom wave velocity is less than 0.76 m/sec and water surface wavelength is greater than twice the water depth. The ripples at the study sites typically exhibit a straight orientation over the transect distance observed at the study site (1,500 ft) and follow expected patterns of wave refraction from shoreline obstructions and wind direction (divers' observations). Surface ripples at the study sites have been observed to be from 2 to 4 inches in height and 3 to 10 inches from crest to crest and may change daily (divers' observations).

In summary, the proposed diffuser site is located in the nearshore zone of southern Lake Michigan approximately 3,500 ft from the shoreline in a relatively flat plain of sand-dominated substrates susceptible to disruption and re-arrangement by surface induced turbulence. The diffuser site does not encroach upon any navigation channels (nearest approximately 6,080 ft distance), docks (closest fishing pier 4,200 ft away), harbors (closest boat ramp and harbor approximately 5,125 ft away), or water intakes (closest water intake 1,640 ft away).

Key findings about the physical characteristics at the proposed diffuser site determined from the Biomonitoring Program and discussed in Attachment 6 include the following.

1. Water column measurements at this site indicate complete vertical mixing over the 28 ft depth.
2. Stratification of the water column due to temperature or density has not been observed and likely does not occur.
3. Bottom substrates consist mainly of sand (76 percent) and silt (21 percent) sized particles.
4. Bottom substrates are frequently moved and re-arranged by currents and wave action resulting from storms and other water surface turbulence.

Nearshore Chemical Characteristics. The chemical water quality of the proposed diffuser site is consistent with expected nearshore conditions for southern Lake Michigan. The biomonitoring program field studies showed no significant concentration gradients were present within the water column at the proposed diffuser site. General water quality parameter concentrations determined in the field indicate characteristics of oligotrophic to mesotrophic water quality conditions, fully oxygenated fresh water of low to moderate conductivity, neutral pH, and typical seasonal temperatures. Water chemistry parameters determined from laboratory analyses of water collected at the study sites are presented in Attachment 6. The water chemistry data is consistent with USEPA STORET monitoring data (1982-1995) for many parameters for the Whiting Water Intake Crib. A STORET inventory retrieval with summary statistics is given in Attachment 7.

The receiving water quality and water chemistry conditions at the proposed diffuser site were consistent with IDEM defined background concentrations monitored at the Whiting Intake (see Table 1-4). These background concentrations are based on Lake Michigan monitoring data and indicate that the lake has an assimilative capacity for many constituents without exceeding the Indiana Water Quality Standards.

Key findings for chemical characteristics at the proposed diffuser site determined from the Biomonitoring Program and discussed in Attachment 6 include the following.

1. Water quality attributes measured in the field and observed water chemistry concentrations reflected the oligotrophic to mesotrophic conditions in the region of the proposed diffuser site.

2. General conditions include high dissolved oxygen concentrations, neutral pH, low nutrient concentrations, and normal seasonal temperature fluctuations.

3. Secchi disk (transparency) depths were more dependent upon effects from local wind patterns and storms than chlorophyll-*a* concentrations which were frequently less than 1.0 milligram per cubic meter.

4. Water chemistry parameters did not indicate thermal stratification of the water column or show horizontal variation in concentration.

Nearshore Biological Characteristics. The extreme southern end of Lake Michigan has been generally classified as mesotrophic (Great Lakes Water Quality Board, 1977). This trophic status is intermediate between oligotrophic (clear water, low nutrient concentration, low biological productivity) and eutrophic (nutrient rich, highly productive). The mesotrophic classification was based on four criteria: phytoplankton, zooplankton, chlorophyll-a, and total phosphorus.

The biological characteristics of the receiving water at the proposed diffuser site are controlled by the natural physical settings. The flat, sandy bottom and naturally constant turbulence combine to exhibit characteristics of a flooded beach. These conditions result in a physically unstable habitat which, combined with fluctuations due to seasonal factors, limit the potential for developing a complex biological ecosystem. Few ecological studies have been conducted previously of this physically unstable "beach water zone" defined as less than 30 ft depth and less than two miles offshore (USFWS, 1970).

Amoco's Lake Michigan Biomonitoring Program was based on the concept that the most exposed communities would be most appropriate to measure (Figure 3-3). Additional focus was directed toward sessile and drifting organisms because of the greater potential for exposure to effluent from a fixed-point discharge. Biomonitoring results presented in Attachment 6 indicated that the phytoplankton drifting assemblage included numerous tychoplanktonic algae (taxa that persist in the water column but more commonly grow attached to a substrate) that were likely re-suspended from the bottom surface. The assemblage of phytoplankton and zooplankton taxa were consistent with expectations for southern Lake Michigan, though their presence and distribution was likely determined primarily by wind-induced lake currents. Benthic (sessile) organisms in particular showed low density and species richness. The frequent disruption of the lake bottom from storms and surface turbulence within the beach water zone effectively created shifting sand substrates that limited complex benthic community development and productivity. Fish were seldom observed at the study sites[9].

Key findings for biological characteristics at the proposed diffuser site determined from the Biomonitoring Program and discussed in Attachment 6 include the following:

1. Fish are not common at the study site. A lack of habitat structure, refugia, and food resources prevent the diffuser location from attracting high numbers of fish. Fish observed in the environs of the study site include non-native gobies and alewives.

2. The benthos assemblage exhibits low richness, low diversity, and a patchy distribution with respect to species and abundance.

3. Spatial and temporal variability of the benthos assemblage was high.

4. Frequent bottom surface disturbances from surface water wave action limits development of a complex benthos assemblage. Organisms that burrow into the substrate to avoid abrasion from shifting sands (oligochaete worms) or hard-shelled organisms (snails, clams, and mussels) that are more protected from abrasion appear to be most common.

5. The phytoplankton assemblages contain green algae, yellow-green algae, and diatoms, flagellates and blue-green algae forms. Diatoms dominate the assemblage. Tychoplanktonic algae re-suspended into the water column from the sediment surface were common. Richness and diversity of the phytoplankton were higher than benthos or zooplankton because of the tychoplanktonic nature of this community.

6. The zooplankton assemblages exhibited low richness and low diversity. The zooplankton assemblage consisted of rotifers, cladocera and copepods. Dominant organisms included the copepod *Diacyclops bicuspidatus thomasi*, *Diaptomus* sp. and *Mesocyclops edax*, and the rotifer *Asplanchna herricki*. Abundance of these organisms was highly variable and reflected a highly patchy distribution.

[9] A summary of representative fisheries obtained from USFWS (1996) is presented in Attachment 8.

7. Low values for fish abundance, phytoplankton and zooplankton density, Secchi disk depth, and chlorophyll-a concentrations were consistent with characteristic of oligotrophic to mesotrophic conditions for Lake Michigan at the proposed diffuser site.

327 IAC 5-2-11.4(b)(4)(A)(v) - Document the physical, chemical, and biological characteristics of the effluent.

The Amoco Outfall 001 effluent is freshwater with a temperature greater than the receiving water, thereby resulting in a positively buoyant discharge plume. The long-term average effluent flow rate is 13 mgd and the multiport diffuser is designed to maintain a port exit velocity of 10 ft/sec at this average flow rate. The diffuser will be designed to operate and provide suitable dispersion over an effluent flow range of 7 to 44 mgd. This is the range of short duration flows observed over three years (1991-1994). Chemical and biological characteristics of Outfall 001 are presented in Volume I Form 2C Part V and Part VII of this NPDES Permit Application. There are two major observations regarding effluent quality: 1) all maximum bioavailable concentrations of constituents are below the Indiana acute aquatic criteria; and 2) based on three years of effluent toxicity biomonitoring using standard USEPA methods and procedures, no acute toxicity has been measured or observed for the 001 effluent.

327 IAC 5-2-11.4(b)(4)(A)(vi) - Document the synergistic effects of overlapping mixing zones or the aggregate effects of adjacent mixing zones.

No mixing zones from other local discharges are located within or adjacent to the proposed Amoco diffuser mixing zone. The Amoco mixing zone will not contact the Lake Michigan shoreline or encroach upon drinking water or industrial intakes. The 0.39 acre mixing zone, which is 50 ft from all points on the diffuser header is about 3,500 ft from the current Outfall 001 side channel discharge.

327 IAC 5-2-11.4(b)(4)(A)(vii) - Show whether organisms would be attracted to the area of mixing as a result of the effluent character.

The effluent character will remain the same as currently discharged from Outfall 001. Temperature differences between ambient lake water and the effluent may attract fish.

The dispersion modeling estimates used an annual temperature differential of 20° C between effluent and ambient receiving water. However, heat dissipation through the 3,500-ft pipe and rapid mixing at the diffuser will reduce the temperature differential that currently exists at Outfall 001. The 10 ft/sec exit velocity at the diffuser ports will effectively create an "avoidance zone" immediately near the diffuser because of the excess energy expenditure required of fish to persist at this location. The proposed diffuser configuration and associated rapid mixing provides a smaller area of attraction than currently exists at outfall 001.

<u>327 IAC 5-2-11.4(b)(4)(B)(i) - The mixing zone would not interfere with or block passage of fish or aquatic life.</u>

The mixing zone will not interfere with or block passage of fish or aquatic life. No migratory routes or preferred passages for fish or benthic organisms capable of self-dispersion are known to exist in the proposed mixing zone area. The mixing zone will not interfere with or block passage of aquatic life dependent upon dispersion by currents and wave action. The size of the mixing zone delineated from the proposed diffuser (0.39 acre, 50 ft from all points on the diffuser header) is minimized to provide rapid and complete mixing within a small area. Since the mixing zone will be located in an area unconfined by immediate shoreline or other structures (3,500 ft from the current Outfall 001) and does not contact any shoreline, no obstruction of any migratory routes or passage of any indigenous aquatic species, including fish, can occur. The 90-ft diffuser header located on the lake bottom will also not be an obstruction to any migratory routes of any indigenous aquatic species.

<u>327 IAC 5-2-11.4(b)(4)(B)(ii) - The level of pollutant permitted in the waterbody would not likely jeopardize the continued existence of any endangered or threatened species listed under Section 4 of the ESA or result in the destruction or adverse modification of such species habitat.</u>

The level of pollutant in the waterbody will not jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modifications to endangered or threatened species' critical habitat. Based on Indiana rules, there are no bioaccumulative chemicals of concern (BCCs) in the effluent, nor is the mixing zone proposed for BCCs. Threatened and endangered species that are recognized under Section 4 of the ESA ths\at occur in Indiana are presented in Attachment 9. Organisms that can occur in the nearshore zone of Lake Michigan that may encounter the mixing zone include birds, fish, crustaceans, mussels, and gastropods. No fish, crustaceans, or gastropods listed for the State of Indiana are indicated as federally recognized endangered or threatened species. The mussels identified as federally threatened or endangered are supported by critical habitats that exist in flowing waters. The proposed mixing zone would not be considered a critical habitat or critical food resource for bird species listed for northern Indiana, which include Peregrine falcon, bald eagle, and interior least tern.

327 IAC 5-2-11.4(b)(4)(B)(iii) - The mixing would not extend to drinking water intakes.

The Amoco mixing zone will not encroach upon drinking water or industrial intakes. The 0.39 acre mixing zone, which is 50 ft from all points on the diffuser header will be about 1,640 ft northeast of the City of Whiting/Amoco intake. The diffuser ports will discharge to the north towards the center of the lake. Amoco Outfall 001 effluent currently meets primary drinking water standards.

327 IAC 5-2-11.4(b)(4)(B)(iv) - The mixing zone would not impair or otherwise interfere with the designated uses of the receiving water or downstream waters.

Indiana Water Quality Standards are applied to protect and maintain the designated uses of waters of the state, including Lake Michigan. Lake Michigan is designated for uses as: a public, industrial, and agricultural water supply; full-body-contact recreation; and support for a well-balanced aquatic community. The water quality criteria (numeric and whole effluent) presented in 327 IAC 2-1.5-8 are based on protecting these uses of the water. Water quality standards given in 327 IAC 2-1.5-8 shall apply as defined by their in-stream derivation at appropriate points based on time, exposure, duration, and frequency. Attainment of the water quality standards at their appropriate points assures continued all designated uses of the waterbody. Amoco's mixing zone will not impair or interfere with the designated uses of Lake Michigan.

Lake Michigan is also used as a source of water for drinking water treatment plants. The nearest point of water intake is the Whiting intake located approximately 1,640 ft from the proposed diffuser. The mixing zone extends only to a distance of 50 ft from the diffuser. For those substances with primary drinking water standards, which are human health safety-based, as established by the Federal Safe Drinking Water Act, Outfall 001 maximum effluent concentrations are already less than these drinking water standards at end-of-pipe (prior to mixing with Lake Michigan) as presented in Table 3-1. In other words, Outfall 001 effluent contains smaller quantities of these substances than the concentrations given as the federal primary drinking water standards. Thus, Amoco's projected mixing zone will not adversely affect Lake Michigan as a source of drinking water.

<u>327 IAC 5-2-11.4(b)(4)(B)(v) - The mixing zone would not promote undesirable aquatic life or result in a dominance of nuisance species.</u>

The mixing zone is not expected to promote undesirable aquatic life or result in a dominance of nuisance species. With the exception of a beneficial reduction in area for mixing with receiving water, the character of the effluent will not change from current Outfall 001 conditions. The promotion of undesirable planktonic or benthic aquatic life, or dominance of nuisance species has not been observed, detected, or documented for the existing effluent discharge from Outfall 001. Increases in resident species or introduced exotic organisms that could possibly attain undesirable or nuisance status would likely result from changes in lake-wide water quality or biological dynamics, and not from the Outfall 001 mixing zone.

Indiana-specific nuisance and non-indigenous species information was unavailable; however, organisms listed as Species of Concern in the Nonindigenous Aquatic Nuisance Species State Management Plan (State of Michigan DEQ 1995) that have been observed or recorded at the proposed mixing zone site are the round goby fish and zebra mussel. The planktonic spiny water flea has not been recorded at the proposed diffuser site and distribution of the spiny water flea is dependent upon lake currents. The round goby fish has been observed after storm events feeding upon amphipod crustaceans associated with tangles of unattached organic debris transported along the lake bottom. It is anticipated that the mixing zone will have negligible effect on the occurrence or distribution of unattached organic debris along the lake bottom. Zebra mussels typically occur on occasional woody debris or small stones that can provide a solid substrate. The construction of the diffuser header and feeder pipe will cause a modification to the lake bottom substrate as the pipeline trench is backfilled and stabilized with rip-rap or similar material that may provide a firm substrate for zebra mussel colonization. It is anticipated that areas of firm substrate exposure will be limited as transport of sand substrate will cover the habitat, hence minimizing overall zebra mussel colonization. The character of the effluent and mixing zone, though, will not promote zebra mussel growth over and above current lake conditions and habitat limitations.

<u>327 IAC 5-2-11.4(b)(4)(B)(vi) - By allowing the additional mixing: (AA) substances will not settle to form objectionable deposits; (BB) floating debris, oil, scum, and other matter in concentrations that form nuisances will not be produced; and (CC) objectionable color, odor, taste, or turbidity will not be produced.</u>

The current Outfall 001 side channel discharge is subject to provisions in the NPDES permit whereupon: (AA) substances will not settle to form objectionable deposits; (BB) floating debris, oil, scum, and other matter in concentrations that form nuisances will not be produced; and (CC) objectionable color, odor, taste, or turbidity will not be produced. The current Outfall 001 complies with this permit stipulation. The effluent character from the proposed diffuser will not change from the current Outfall 001 discharge. Therefore, it is anticipated that the discharge from the diffuser will meet the following conditions: (AA) substances will not settle to form objectionable deposits; (BB) floating debris, oil, scum, and other matter in concentrations that form nuisances will not be produced; and (CC) objectionable color, odor, taste, or turbidity will not be produced.

<u>327 IAC 5-2-11.4(b)(4)(C) - In no case shall a mixing zone for a discharge into the open waters of Lake Michigan be granted that exceeds the area where discharge-induced mixing occurs.</u>

As presented above, the Outfall 001 diffuser will be a discharge to the open waters of Lake Michigan. The applicable mixing zone dispersion is capped to where discharged-induced mixing ceases. Discharge-induced mixing ceases at the edge of the CORMIX2 DIMZ, which is equivalent to the edge of the Near-Field Zone where plume velocity approaches ambient lake velocity. Therefore, the applicable mixing zone dispersion and distance are reduced to the corresponding DIMZ values (54:1 and 0.39-acre mixing zone 50 ft from all points on the diffuser header).

3.3 OVERALL SUMMARY

The background information on Lake Michigan, the recent biological studies of the proposed Amoco multiport diffuser site, and compliance with state regulations and federal mixing zone guidelines all demonstrate that implementation of a mixing zone is appropriate for Outfall 001.

TABLE 3-1. COMPARISON OF OUTFALL 001 CHARACTERISTICS TO FEDERAL PRIMARY DRINKING WATER STANDARDS

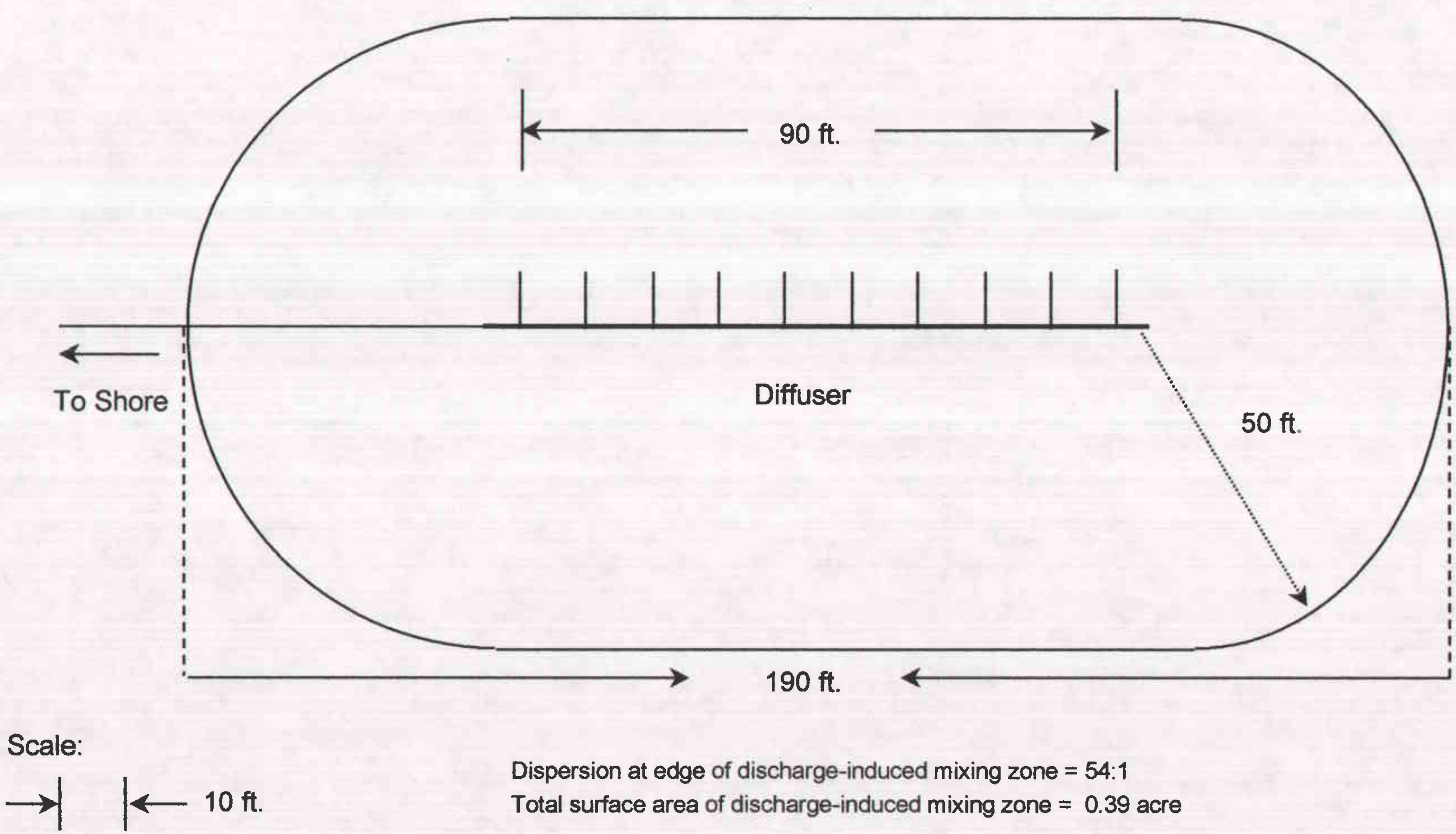
CONSTITUENTS (a)		NPDES PERMIT APPLICATION CHARACTERIZATION DATA	DRINKING WATER MAXIMUM CONTAMINANT LEVEL (b)
		Maximum Daily Value	
METALS			
Arsenic (Total)	µg/L	21	50
Barium (Total)	µg/L	90	2,000
Beryllium (Total)	µg/L	2	4
Chromium (Total)	µg/L	30	100
Copper (Total)	µg/L	29	1,300 (c)
Lead (Total)	µg/L	13	15 (c)
Nickel (Total)	µg/L	7	100
Selenium (Total)	µg/L	45	50
OTHER SUBSTANCES			
Cyanide (Total)	µg/L	19	200
Nitrate-N - Nitrite-N	mg/L	0.5/<1.0	10
Fluorides	mg/L	0.3	4

Notes:

(a) Constituents presented have been detected in Amoco's treated effluent. Other constituents with federal primary drinking water standards were not detected in the effluent.

(b) EPA National Drinking Water Regulations in 40 CFR Part 141, except where noted.

(c) Action levels from 40 CFR 141 Subpart I.



Prepared For

AMOCO OIL COMPANY
WHITING REFINERY
Whiting, Indiana

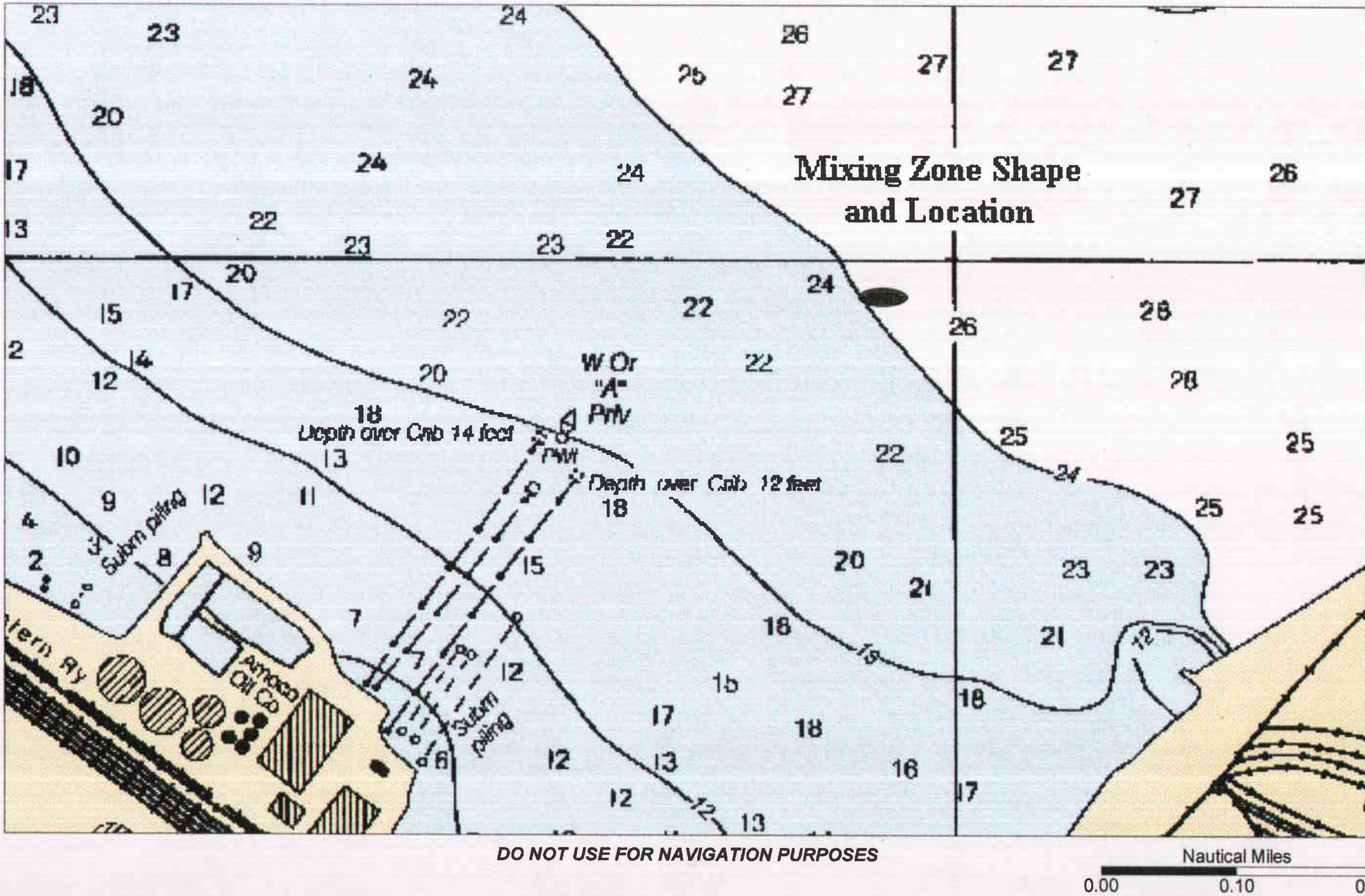
THE ADVENT GROUP, INC.
Rosslyn, Virginia

**FIGURE 3-1.
ALTERNATE MIXING
ZONE DELINEATION**

97515\Task2\Fig3-1.ppt

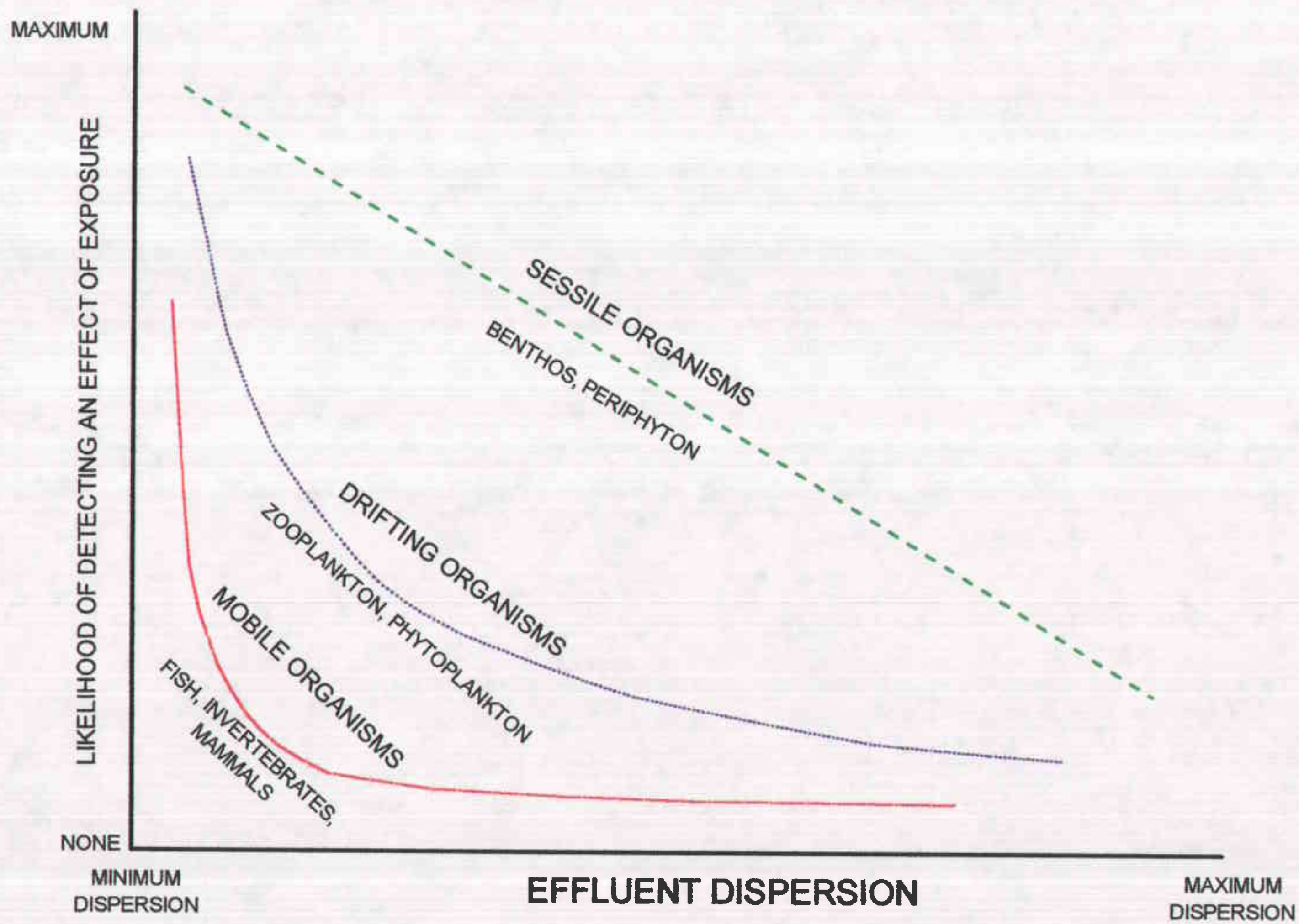
Mar 1998

Figure 3-2
Mixing Zone Shape and Location in Lake Michigan



From: Calumet and Indiana Harbors NOAA Chart 14929 (Jan. 20/90)

FIGURE 3-3. CONCEPTUAL COMMUNITY SENSITIVITY



SECTION 4

SECTION 4.0
MIXING ZONE DEMONSTRATION CONCLUSION

Amoco Oil Company, Whiting Refinery has demonstrated that the implementation of a mixing zone in Lake Michigan for treated effluent, particularly through the use of a high-rate multiport diffuser, is protective of the environment. This mixing zone will not be implemented for any bioaccumulative chemicals of concern defined in 327 IAC 2-1.5-6. The information provided in this volume (Volume II Revised) demonstrates that a mixing zone application is appropriate for Outfall 001. In addition, information is provided in this volume and Volume II (submitted August 1994) for consideration by the Commissioner that the mixing zone will not cause harm based on human health, aquatic life, and wildlife criteria. This conclusion is based on the water quality criteria designated to protect the use of Lake Michigan and the assessment of the local biological community. The engineering of the diffuser and resulting dispersion support this conclusion.

The receiving water, Lake Michigan, is designated for use as: a public, industrial, and agricultural water supply; full body contact recreation; and support for a well-balanced aquatic community. The water quality criteria (numeric and whole effluent) presented in 327 IAC 2-1.5-8 are based on protecting the uses of the water. If the criteria are not exceeded in the receiving water, then the use of the water is not impaired and the designated use is maintained. As presented in Table 1-4, the quality of Lake Michigan, as measured at the Whiting intake, does not exceed the water quality criteria for the listed substances. Therefore, the Indiana portion of Lake Michigan does have assimilative capacity for these Table 1-4 substances. Available assimilative capacity is a prerequisite for granting a mixing zone.

Another consideration, before proceeding with a mixing zone demonstration, is to confirm that the effluent quality is equivalent to that established by technology-based limits. That is, a mixing zone cannot be used to attain technology-based permit limits. As presented in Table 1-1, Amoco produces treated effluent that meets the existing technology-based limits. Effluent quality based on historical wastewater treatment plant performance is better than technology-based limits. Hence, Amoco is not using a mixing zone in place of wastewater treatment to achieve technology-based and existing permit limits. The mixing zone demonstration process for this effluent is appropriate.

The biological community most susceptible with respect to effects of a mixing zone has been identified by the USEPA as the sessile organisms (e.g., benthic community). The benthic community has been found to be poorly developed in the vicinity of the proposed diffuser site due to natural dynamic physical characteristics (e.g., fine sands and turbulence). The portions of the biological community in this area that are also susceptible to the effects of a mixing zone are the drifting water column organisms (e.g., plankton). Plankton are also good candidates for evaluation as they represent primary producers and primary consumers in this area of the lake. Based on literature review and diffuser site field studies, the abundance, diversity, composition, and function of the plankton and benthos biological are typical for a turbulent habitat. In addition, the evaluation of biological communities did not indicate an impact that could be associated with the existing Amoco discharges (presented in Volume II and Attachment 6). The deeper water and engineered structure at the proposed mixing zone will induce immediate and more rapid mixing within an area smaller than the current outfall area, thus providing an additional degree of safety to the receiving waters. As a result, the continued health of the benthic and planktonic community is expected.

Amoco has used a scientifically sound approach to identify and evaluate possible adverse consequences from chemical impacts of its Outfall 001 effluent. Acute toxicity has not been observed in Outfall 001 effluent. Amoco has proposed installation of a new multiport diffuser system where a mixing zone is defined as a ratio of 54:1 within a 50-ft distance. This proposed improvement over the current discharge structure would mean that mixing would occur within a small area (0.39 acre). The mixed effluent meets every applicable standard whether derived to protect human health (e.g., drinking water criteria and standards and Lake Michigan-specific standards) or aquatic life (e.g., water quality criteria).

Therefore, Amoco has demonstrated that a mixing zone for its Outfall 001 effluent is appropriate and meets the requirements of Indiana rules for a mixing zone, as well as the national guidance of the USEPA. The approaches taken by Amoco, and the key findings, as detailed elsewhere in Volumes I and II, are briefly summarized below:

- Amoco is proposing to install a submerged multiport high-rate diffuser in 28-30 ft of water approximately 3,500 ft from shore to assure rapid and immediate mixing in a small area.

- According to the USEPA CORMIX2 model, a discharge-induced dispersion of 54:1 will be achieved within 50 ft of the diffuser. This CORMIX2 DIMZ dispersion can be directly utilized for calculating acute wasteload allocation values.

- The CORMIX2 model predicts a far-field mixing zone dispersion of 77:1 achieved at 500 ft from the diffuser. However, since the Amoco Outfall 001 discharge is to the open waters of Lake Michigan, the far-field dispersion is reduced to the CORMIX2 DIMZ dispersion (54:1) where discharge-induced mixing ceases (50 ft). The mixing zone dispersion of 54:1 can be directly utilized for calculating acute and chronic wasteload allocation values.

- The proposed diffuser location exhibits a natural, constant turbulence and unstable sandy substrate. This harsh physical setting limits development of the benthic community. Hence, potential aquatic community impacts from effluent may be better detected by focusing also on the plankton as opposed to only on the benthic community. Thus, Amoco's biological field assessments have appropriately focused on the structure and function of the benthos and plankton community.

Based on the findings presented in this report, a mixing zone should be applied to Amoco's NPDES Permit to derive acute and chronic effluent limitations for Outfall 001. Implementation of the mixing zone will continue to protect the designated uses of Lake Michigan. In addition, the mixing zone will not cause harm based on human health, aquatic life, and wildlife. Hence, under Indiana law, Amoco qualifies for a mixing zone.

ATTACHMENTS

1

ATTACHMENT 1

FEDERAL MIXING ZONE GUIDANCES

ATTACHMENT 1

OVERVIEW OF FEDERAL REGULATIONS AND GUIDANCE ON USE OF MIXING ZONES

Federal Regulations and Guidance

Regulatory establishment of mixing zones first occurred in the late 1960s and the early 1970s when thermal pollution from steam-electric power plants was of concern. During the 1970's, following the establishment of discharge limitations based on the Federal Water Pollution Control Act of 1972, requirements and guidelines were issued to implement mixing zones that were environmentally protective. The mixing zone concept was applied more broadly, based on time and exposure assessments, to meet effluent limitations placed on conservative constituents, such as total dissolved solids (TDS). During the 1980s, the definition and allowance of mixing zones were again expanded to include specific constituents for which USEPA had derived receiving water quality criteria. The USEPA ambient water quality criteria presented in the 1986 *Quality Criteria for Water* (or Gold Book) were the foundation for the Indiana Water Quality Criteria. These criteria are based on magnitude (maximum and continuous), duration (acute - one hour or chronic - four days), and frequency (once per three years) statements. This process of integrating time and exposure with concentration was the basic scientific framework for assuring that mixing zones are protective to aquatic life. Part of the rationale for defining the point of application of acute and chronic receiving water criteria using a mixing zone was to allow a small area (where water quality standards do not apply) to exist without causing adverse effects to the overall waterbody. The delineation of a regulatory mixing zone was based on the two areas downstream from an outfall: the Zone of Initial Dilution, outside of which no acute toxicity could occur, and total mixing zone, outside of which no chronic toxicity could occur. The purpose of this mixing zone definition was to minimize the area and time of exposure a wastewater discharge would have on the local biota.

In the 1990s, the USEPA reiterated its policy to allow mixing zones in streams, lakes, estuaries, and oceans for the application of water quality criteria. In the 1992 and 1995 federal Water Quality Standards, 40 CFR 131 Subpart D, and 40 CFR 132 Appendix F, the applicability of mixing zones is recognized. Mixing zone concepts have been confirmed in various guidance documents such as the 1991 *Technical Support Document for Water Quality-based Toxics Control* (TSD), the 1993 (updated 1996) *Training Manual for NPDES Permit Writers* (TMPW), and the 1993 (updated 1994) *Water Quality Standards Handbook* (WQSH). These guidance documents present revised and updated mixing zone concepts that reflect USEPA's policy of integrating effluent chemical characteristics, whole effluent toxicity, and receiving water bioassessments into the process of establishing water quality-based effluent limits. In addition, revisions were made as more scientific information became available on the relationship between time and exposure of organisms to constituents and the subsequent effects on the organisms and surrounding ecosystem.

The USEPA rules and guidance for mixing zones recognize that states may adopt mixing zones and specify the dimensions. As the water quality standards program elements were clarified by the USEPA, 49 States, including all the states bordering Lake Michigan, have promulgated regulations to demonstrate whether the use of a mixing zone for defining the point of application for a receiving water criterion is appropriate in a discharge permit. The states bordering Lake Michigan allow the use of default mixing zones in the Lake of 10:1 with the demonstration of an alternative mixing zone on a case-by-case basis in accordance with Great Lakes Water Quality Guidance (per preliminarily adopted Illinois and Wisconsin regulations and final Michigan regulations).

<u>General Mixing Zone Hydraulic Characteristics</u>

Individual mixing zones are unique to each effluent discharge and to each environmental setting. The mixing achieved from any effluent discharge can be described from the information listed below:

- Type of effluent discharge structure and configuration;
- Effluent physical characteristics (density, flow rate); and
- Receiving water hydraulic and physical characteristics (depth, velocity, density).

Each effluent plume can be characterized by identifying specific "regions" or areas within the mixing zone, although the location and configuration will differ for each plume. The pertinent regions of a mixing zone are:

1) Near-Field Mixing, including:

   a) Jet Entrainment Zone - Typically within a short distance downstream from the effluent discharge point resulting from initial momentum of the effluent into the receiving water. Dispersion is a function of the outfall characteristics.

   b) Transition Mixing Zone - A combination of lateral and gravitational spreading and natural ambient diffusion that occurs during the transition from jet entrainment mixing to far-field mixing.

2) Far-Field Mixing Zone - Longitudinal, lateral and vertical mixing due to natural receiving water ambient diffusion. Mixing in this area is a function of receiving water characteristics.

Jet Entrainment Zone

The jet entrainment zone is the initial effluent mixing point in the receiving water. It represents the zone in which the maximum reduction in effluent concentration occurs. The size of the jet entrainment zone is directly related to the difference between initial effluent velocity (flow) and the receiving water velocity in the discharge area as well as the initial density difference that exists between the effluent and the receiving water. The rate of dilution is quite rapid in the first few moments after exiting the discharge point. The width of the jet entrainment zone is related to the method of discharge with the average concentration across the plume cross section being about one-half to one-third the maximum centerline concentration. In this zone, designers of an outfall can affect the initial mixing characteristics through manipulation of outfall design variables. Multiport diffusers are designed so that each diffuser port will act as an individual plume for entrainment prior to merging. As presented in the USEPA 1991 TSD, the typical design effluent exit velocity from a diffuser port is around 10 ft/sec. For this velocity, the jet entrainment zone for a diffuser extends to about one diffuser length downstream[1] and the diffuser induced

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[1] Lee, J.H. and G.H. Jirka; "Multiport Diffuser as Line Source of Momentum in Shallow Water", Water Resources Research, 1980. Vol. 16, No. 4, pp. 695-708.

dispersion that can be obtained within this distance is on the order of a 50 to 100 times reduction of the effluent concentration. The reduction in effluent concentration based on the ratio of effluent concentration to receiving water concentration, as predicted or measured, will be referred to as the dispersion ratio in this report.

The federal regulatory term "ZID" is analogous to the jet entrainment zone. A typical definition for a ZID is a small area where rapid and immediate mixing occurs.

Transition Mixing Zone

The transition mixing zone has several hydraulic factors acting on the effluent/receiving water mixing regimes. First, the effluent still has momentum that causes turbulent mixing with the receiving water. The plume also undergoes lateral gravitational spreading that occurs due to the density difference that may exist between the effluent and the receiving water. Additionally, the receiving water ambient diffusion forces are working to mix receiving water and effluent together. The overall mixing process continues at a much slower rate in this zone. The transition zone, where the effluent discharge still has influence, slowly transcends into the far-field mixing zone where the receiving water completely dominates the mixing. The end of the transition zone is the end of the near field zone.

Far-Field Mixing Zone

As the turbulent effluent plume travels farther away from the source, the effluent characteristics become less important. Far-field dispersion is totally dependent upon the receiving water ambient diffusion. Eventually, the effluent will become completely mixed laterally and vertically in the receiving water by natural ambient diffusion (far-field dispersive forces). The federal regulatory term of total mixing zone (usually defined in the far-field zone) is typically associated with the chronic toxicity limit (i.e., outside this zone, no chronic toxicity may occur) and is usually geographically limited. The distinction between near-field and far-field is made purely on a hydrodynamic basis. It is unrelated to any regulatory mixing zone definitions that address prescribed water quality standards.

Mixing Zone Specifications

The USEPA guidance documents recognize the use of mixing zones and state numerous mixing zone specifications. A summary of some of the specifications, including the goal of a mixing zone evaluation step and the information to be provided to answer the objective, is presented in Table A1-1. The focus of USEPA guidance includes:

- Determination of the mixing zone boundaries and analysis procedures;
- Minimization of the size of mixing zones;
- Prevention of lethality to passing organisms;
- Prevention of bioaccumulation problems;
- Recommendation of outfall design;
- Designation of critical design periods for water bodies; and,
- Description of discharge induced mixing and far-field mixing modeling techniques.

The 1991 EPA TSD specifies that three independently established mixing zone specifications may apply, which include the following:

1. The jet entrainment zone, which is sized to prevent lethality to passing organisms. Acute criteria are met at the edge of this zone, and outside this zone no acute toxicity should occur to aquatic organisms. This zone is also known as the Zone of Initial Dilution (ZID).

2. A chronic mixing zone (or total mixing zone) is sized to protect the ecology of the waterbody as a whole. Chronic criteria are met at the edge of this zone, and outside this zone no chronic toxicity should occur to aquatic organisms.

3. A health criteria mixing zone is sized to prevent significant human risks. This typically implies that mixing zones not encroach on drinking water intakes nor result in significant health risks to average consumers who might uptake sufficient quantities of fish and shellfish that may be reasonably expected to reside in the affected zone for sufficient exposure periods. These exposure periods would result in a net bioaccumulation of constituents that could subsequently result in a human health risk.

The mixing zone size may be limited by any single specification or all three of these specifications.

The 1991 TSD provides the guidance for assessing and defining mixing zones, the application criteria to mixing zones, and recommendations for outfall design. TSD Section 4, "Exposure and Wasteload Allocation," discusses assessment of mixing zones in receiving waters. In the overview, the EPA divides the transport of treated effluent in a waterbody into two stages:

- First - mixing and dilution as determined by the initial momentum and buoyancy of the discharge. As previously presented in this report, this is called the jet entrainment zone which is analogous to the Zone of Initial Dilution.
- Second - the area in which the effect of initial momentum and buoyancy is overridden and the wastewater is mixed primarily by ambient turbulence. In this report, this is the far-field mixing zone or total mixing zone.

The EPA recommends that regulatory agencies evaluate mixing and outlines methods to evaluate dispersion and set mixing zones in Section 4 of the TSD. Several computer models are recommended for mixing zone analyses. These models were developed to divide the entire mixing region into several zones with distinct behavior (such as individual mixing processes in the near-field and in the far-field). Each model requires some schematizations of the complex and arbitrary ambient and discharge conditions that may prevail at any discharge site. These schematizations are needed to conform to the requirements of the individual models. There are two main groups of zone models commonly used to evaluate mixing: integrated zone models and jet integral models. The integrated zone model, 1992 Cornell Mixing Zone Expert System[2] CORMIX2, was used to evaluate the mixing between treated effluent discharged through a multiport diffuser and Lake Michigan. Modeling rationale is further discussed in Section 2 of this volume.

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[2] Akar, P.J. and G.H. Jirka 1992. "CORMIX2: An Expert System for Hydrodynamic Mixing Zone Analysis of conventional and Toxic Submerged Multiport Diffuser Discharges", Technical Report, USEPA, ERL, Athens, GA.

The allowable size of a mixing zone is determined on a case-by-case basis, taking into account the critical resource area that needs to be protected and the assimilative capacity of the receiving water. As a mixing zone is used to define the point of application of receiving water criteria, it is necessary to first determine that the receiving water meets the criteria for its designated use. As presented in Table 1-4 (Section 1 of this volume), average Lake Michigan background concentrations are less than the concentrations allowed by the water quality criteria established to protect the use of Lake Michigan. This comparison between background concentrations and water quality standards confirms that the receiving water has available assimilative capacity, and therefore can incorporate a delineated mixing zone.

TABLE A1-1. FEDERAL AND INDIANA MIXING ZONE SPECIFICATIONS

GOAL	OBJECTIVE	APPROACH	INFORMATION/RESPONSE
Ideally, holistic concepts to determine that a mixing zone is protective.[a,d]	Consider all the impacts to the water body and the impacts that the small area of decreased water quality within the mixing zone will have on the surrounding ecosystem and water body uses.[a,d]	Use a multistep data collection and analysis procedure. - Identify all ecological and cultural data for upstream and downstream water bodies; collect data on all present and future discharges to the water body; assess relative environmental value and level of protection needed for the water body; allocate environmental impact for a discharge applicant.[a,d]	Background water quality conditions. (Federal[a,c,d] and Indiana[f]) Present and anticipated use of receiving water. (Indiana[f]) Measured and anticipated effect of discharge on receiving water quality. (Federal[a,c,d] and Indiana[f]) Will not cause harm to aquatic life and human health. (Indiana[e,f])
Waterbody integrity protected, maintained, and restored.[a,b,c,d,e]	Assimilative capacity available.[a,c,d,f]	Consider desired uses of water and criteria for use.[a,c,d,e]	Background water quality - physical, chemical and biological. (Federal[a,c,d] and Indiana[f,g]) Present and anticipated uses of receiving water. (Indiana[f]) Measured and anticipated effect of discharge on receiving water quality. (Federal[a,c,d] and Indiana[e,f,g]) Mixing zone should not be considered a place where effluent is treated, that is technology-based limits achieved. (Federal[b] and Indiana[f])

TABLE A1-1. FEDERAL AND INDIANA MIXING ZONE SPECIFICATIONS

GOAL	OBJECTIVE	APPROACH	INFORMATION/RESPONSE
Waterbody integrity protected, maintained, and restored.[a,b,c,d,e] (Continued)	Protect critical areas.[a,d,f]	Consider location of mixing zone.[a,c,d,f]	Location of mixing zone does not extend to drinking water intake. (Federal[a,c,d] and Indiana[g]) Impact on spawning and nursery areas. (Indiana[g]) Size, shape, and location of mixing zone. (Federal[a,c,d] and Indiana[g]) Mixing zone boundaries. (Federal[a,c,d,] and Indiana[g]) Mixing zone does not block passage of aquatic life. (Federal[a,c,d] and Indiana[g]) Mixing zone does not promote undesirable aquatic life. (Federal[c] and Indiana[g]) Substrate characteristics and geomorphology (Indiana[g]); impact of mixing zone on sessile organisms. (Federal[c,d])
Waterbody integrity protected, maintained, and restored.[a,b,c,d,e] (Continued)	No lethality to passing organisms.[a,b,d]	Minimize size of elevated concentration isopleths within the mixing zone.[a,b,d]	Degree of discharge induced mixing. (Federal[a,b,c,d] and Indiana[g]) Mixing zone shall be free of substance or combination of substances that are acutely toxic. (Indiana[e,g])

TABLE A1-1. FEDERAL AND INDIANA MIXING ZONE SPECIFICATIONS

GOAL	OBJECTIVE	APPROACH	INFORMATION/RESPONSE
Definable mixing zone extent and magnitude.[a,c,d,g]	Define application point for short-term and long-term aquatic criteria, i.e., AAC or TU_a at edge of ZID, CAC or TU_c at the edge of TMZ.[a,b,c,d,e,f]	Spatial definitions and achievement rapid immediate mixing.[a,d,e,f]	Mixing zone location, size, shape, boundaries, and dilution ratio. (Federal[a,c,d] and Indiana[g]) In lakes, a circle with a specified radius is preferred. (Federal[d]) Manner (outfall design) by which diffusion/dispersion occurs. (Federal[a,c,d] and Indiana[g]) Maximize initial dilution. (Federal[a] and Indiana[f,g]) Location where discharge-induced mixing ceases in lakes. (Federal[c] and Indiana[g]) Physical, chemical, and biological characteristics of effluent. (Indiana[f,g])

Federal References:

(a) USEPA, March 1991, *Technical Support Document for Water Quality-based Toxics Control*, USEPA/505/2-90-001. (TSD).
(b) USEPA, December 1996, *Training Manual for NPDES Permit Writers*, USEPA 833-B-93-003. (TMPW).
(c) USEPA, March 1995, "Final Water Quality Guidance for the Great Lakes System", 53 Federal Register 15366. (GLI).
(d) USEPA, September 1993 (updated 1994), *Water Quality Standards Handbook*, Second Edition, USEPA 823-B-93-002. (WQSH).

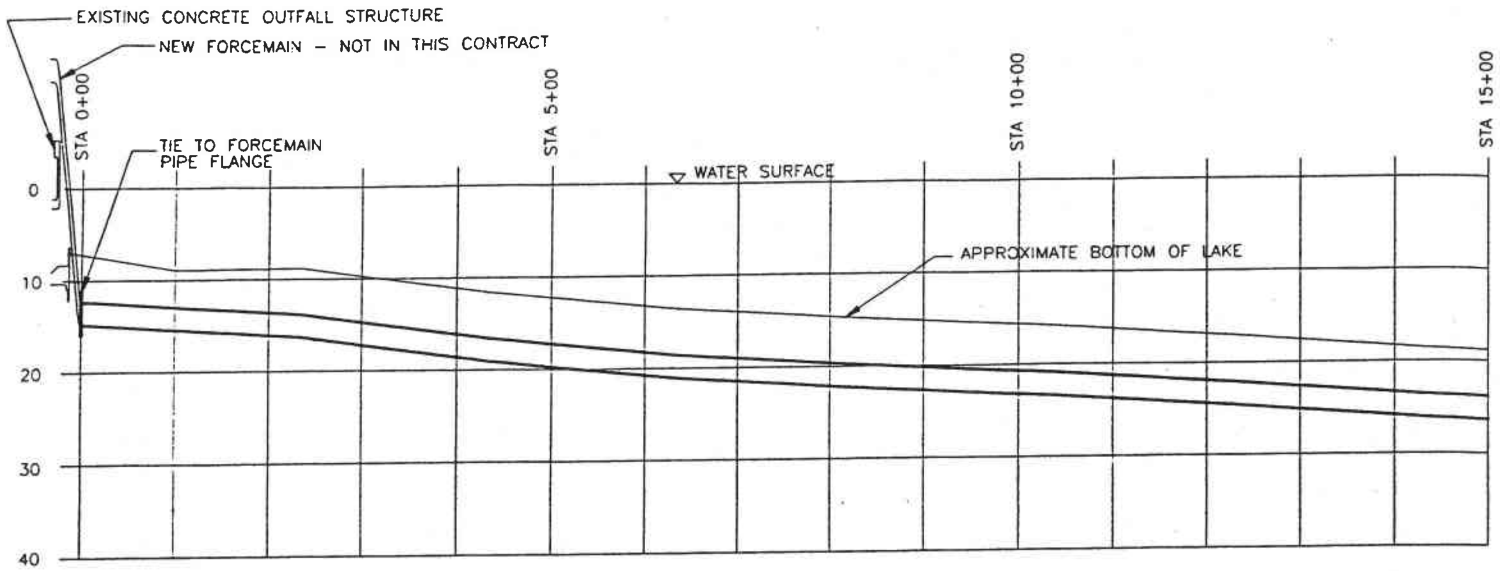
Indiana References:

(e) 327 IAC 2-1.5, *Water Quality Standards*.
(f) 327 IAC 5-2, *Industrial Wastewater NPDES and Pretreatment Programs*.
(g) 327 IAC 5-2-11.4(b).

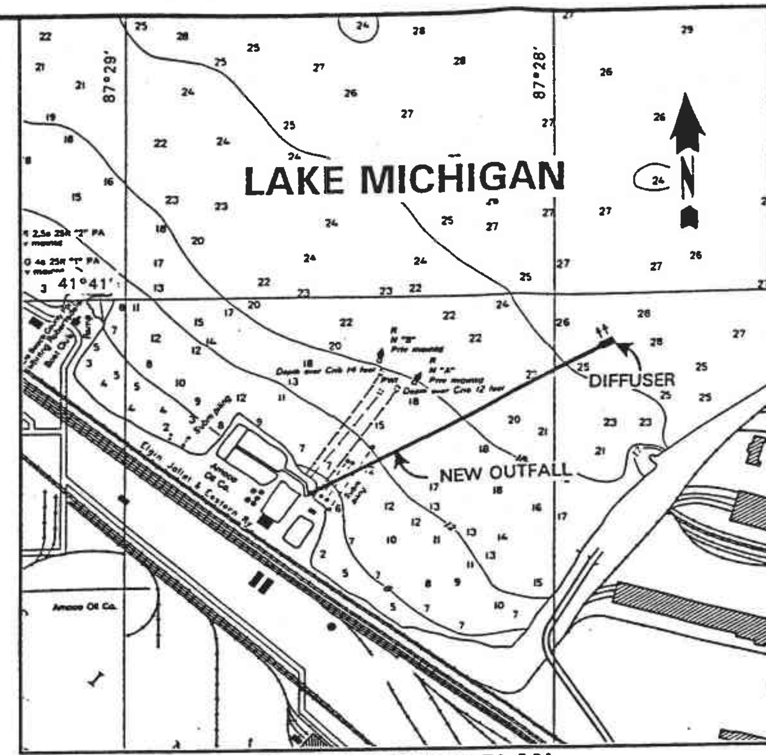
2

ATTACHMENT 2

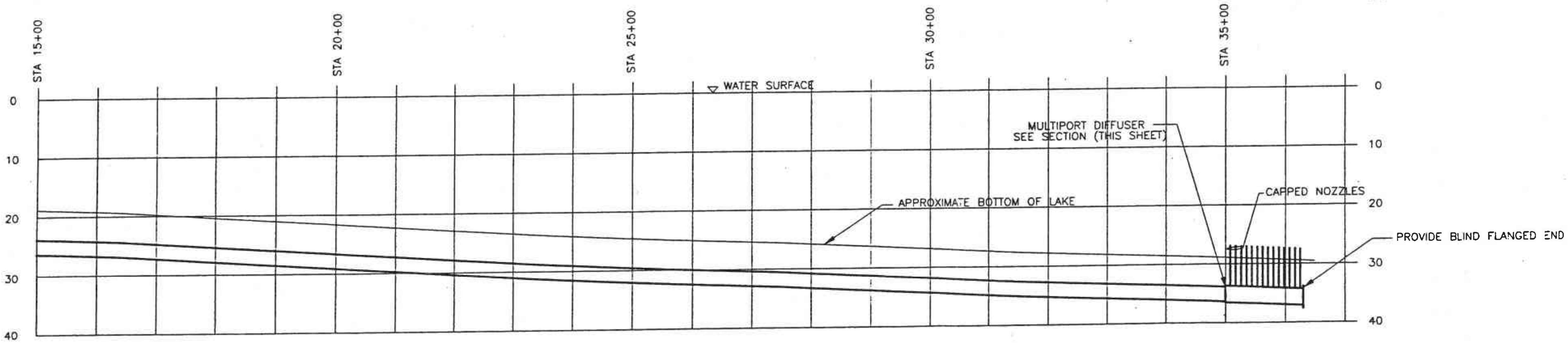
PRELIMINARY DIFFUSER DESIGN
(No change from Volume II, August 1994)



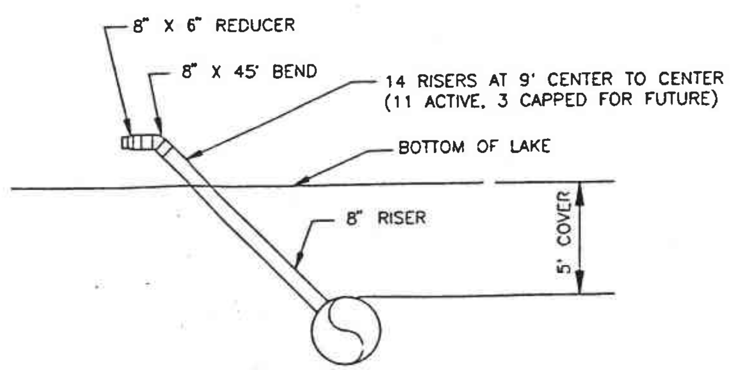
OUTFALL PROFILE
SCALE: 1" = 200' HORIZ.
1" = 20' VERT.



SITE LOCATION PLAN
OUTFALL AND DIFFUSER



OUTFALL PROFILE
SCALE: 1" = 200' HORIZ.
1" = 20' VERT.



MULTIPORT DIFFUSER CROSS SECTION
N.T.S

NO.	DATE	BY	REVISION

ISSUED	BY	DATE	PROJ	APPN

NOTES

DWG NO.	REFERENCE DRAWINGS

PRELIMINARY

PROJ NO. 64527 APPN NO.

Amoco Oil Company
ENGINEERING DEPARTMENT CHICAGO ILL.

OUTFALL PLAN, PROFILE
AND DIFFUSER

THE ADVENT GROUP, INC.

DIV. UTILITY		LOCATION WHITING	
DATE 8-1-94	SCALE NOTED	SHEET 1	OF 1
ENGRD.	CHKD. SCR	DRAWN NLF	APPVD. SCR

DWG.D-7121-SK2 P3

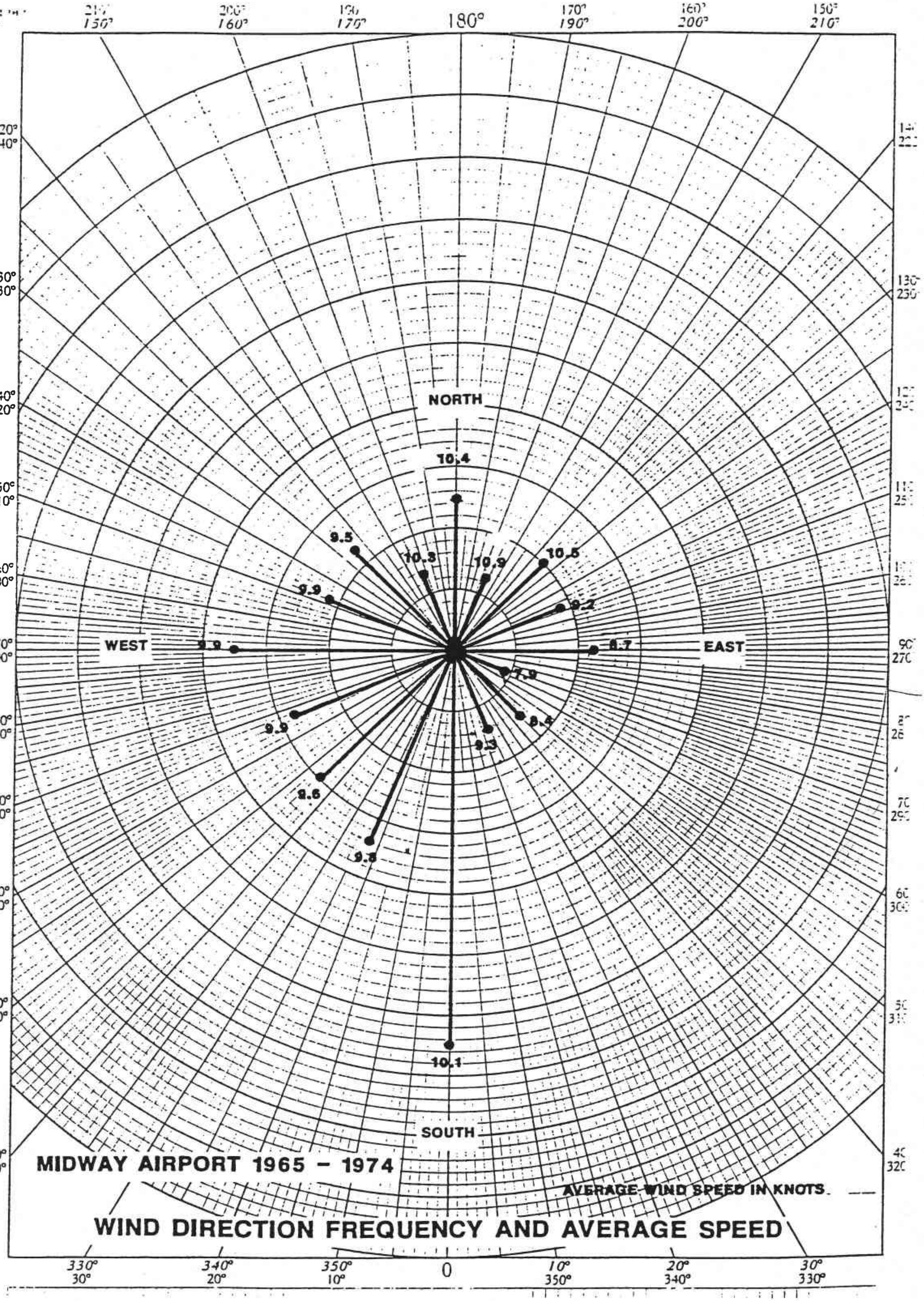
PLOT DATE 8-12-94

i-627\PP-02

3

ATTACHMENT 3

WIND ROSE
(No change from Volume II, August 1994)



NORTH
SOUTH
EAST
WEST
10.4
9.5
10.3
10.9
10.5
9.2
9.9
8.7
7.9
8.4
9.3
9.9
8.6
9.8
10.1
MIDWAY AIRPORT 1965 - 1974
AVERAGE WIND SPEED IN KNOTS
WIND DIRECTION FREQUENCY AND AVERAGE SPEED
180°
0

4

ATTACHMENT 4

CORMIX2 MODEL OUTPUT

(No change from Volume II, August 1994)

CORMIX2 PREDICTION FILE:

```
                            CORNELL MIXING ZONE EXPERT SYSTEM
Subsystem CORMIX2:                                                  Subsystem
version:
 Submerged   Multiport   Diffuser   Discharges
CMX2_v.2.10_____________May_1993
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------

CASE DESCRIPTION
 Site name/label:          SITE^B
 Design case:              0.10mps
 FILE NAME:                cormix\sim\sitebv3 .cx2
 Time of Fortran run:      07/22/94--12:03:32

ENVIRONMENT PARAMETERS (metric units)
 Unbounded section
 HA     =       8.69  HD     =       8.69
 UA     =       .100  F      =       .047 USTAR = .7647E-02
 UW     =      2.000  UWSTAR= .2198E-02
 Uniform density environment
 STRCND=  U           RHOAM =   999.7019

DIFFUSER DISCHARGE PARAMETERS (metric units)
 DITYPE=unidirectional_perpendicular
 BETYPE=unidirectional_without_fanning
 BANK  =  LEFT      DISTB =   1083.70  YB1    =   1070.00  YB2  = 1097.40
 LD     =      27.40  NOPEN =   10       SPAC   =      3.04
 D0     =       .152  A0     =       .018 H0     =       .50
 GAMMA =      90.00  THETA =        .00
 SIGMA =        .00  BETA   =     90.00
 U0     =      3.136  Q0     =       .569        = .5690E+00
 RHO0   =   995.6470  DRHO0 = .4055E+01  GP0    = .3978E-01
 C0     = .1000E+03  CUNITS=   PERCENT
 IPOLL =  1          KS     = .0000E+00  KD     = .0000E+00

FLUX VARIABLES - PER UNIT DIFFUSER LENGTH (metric units)
 q0    = .2077E-01  m0    = .6512E-01  j0    = .8260E-03  SIGNJ0  =  1.0
 Associated 2-d length scales (meters)
 lQ=B   =       .007 lM     =       7.38  lm     =      6.51
 lmp    =   99999.00  lbp    =   99999.00  la     =   99999.00

FLUX VARIABLES - ENTIRE DIFFUSER (metric units)
 Q0    = .5690E+00  M0    = .1784E+01  J0    = .2263E-01
 Associated 3-d length scales (meters)
 LQ     =       .43  LM     =     10.26  Lm    =      13.36  Lb   =    22.63
                                           Lmp  =  99999.00 Lbp =  99999.00

NON-DIMENSIONAL PARAMETERS
 FR0    =     193.18  FRD0   =     40.32  R      =     31.35
 (slot)               (port/nozzle)

FLOW CLASSIFICATION

 2  Flow class (CORMIX2)       =    MU2    2
 2  Applicable layer depth HS =     8.69   2
```

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
C0 = .1000E+03 CUNITS= PERCENT
NTOX = 0
NSTD = 0
REGMZ = 0
XINT = 1000.00 XMAX = 1000.00

X-Y-Z COORDINATE SYSTEM:
ORIGIN is located at the bottom and the diffuser mid-point:
1083.70 m from the LEFT bank/shore.
X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 20 display intervals per module

BEGIN MOD201: DIFFUSER DISCHARGE MODULE

Profile definitions:
BV = Gaussian 1/e (37%) half-width, in vertical plane normal to trajectory
BH = top-hat half-width, in horizontal plane normal to trajectory
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH
.00	.00	.50	1.0	.100E+03	.01	13.70

END OF MOD201: DIFFUSER DISCHARGE MODULE

BEGIN MOD271: ACCELERATION ZONE OF UNIDIRECTIONAL CO-FLOWING DIFFUSER

In this laterally contracting zone the diffuser plume becomes VERTICALLY FULLY
MIXED over the entire layer depth (HS = 8.69m).
Full mixing is achieved after a plume distance of about five
layer depths from the diffuser.

Profile definitions:
BV = layer depth (vertically mixed)
BH = top-hat half-width, in horizontal plane normal to trajectory
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH
.00	.00	8.69	1.0	.100E+03	8.69	13.70
.69	.00	8.69	54.0	.185E+01	8.69	13.35
1.37	.00	8.69	54.0	.185E+01	8.69	13.05
2.06	.00	8.69	54.0	.185E+01	8.69	12.79
2.74	.00	8.69	54.0	.185E+01	8.69	12.56
3.42	.00	8.69	54.0	.185E+01	8.69	12.36
4.11	.00	8.69	54.0	.185E+01	8.69	12.18
4.80	.00	8.69	54.0	.185E+01	8.69	12.03
5.48	.00	8.69	54.0	.185E+01	8.69	11.89
6.16	.00	8.69	54.0	.185E+01	8.69	11.76
6.85	.00	8.69	54.0	.185E+01	8.69	11.65

7.53	.00	8.69	54.0	.185E+01	8.69	11.55
8.22	.00	8.69	54.0	.185E+01	8.69	11.47
8.91	.00	8.69	54.0	.185E+01	8.69	11.39
9.59	.00	8.69	54.0	.185E+01	8.69	11.33
10.28	.00	8.69	54.0	.185E+01	8.69	11.29
10.96	.00	8.69	54.0	.185E+01	8.69	11.25
11.65	.00	8.69	54.0	.185E+01	8.69	11.22
12.33	.00	8.69	54.0	.185E+01	8.69	11.21
13.02	.00	8.69	54.0	.185E+01	8.69	11.20
13.70	.00	8.69	54.0	.185E+01	8.69	11.19

Cumulative travel time = 87. sec

END OF MOD271: ACCELERATION ZONE OF UNIDIRECTIONAL CO-FLOWING DIFFUSER

BEGIN MOD251: DIFFUSER PLUME IN CO-FLOW

Phase 1: Vertically mixed, Phase 2: Re-stratified

Phase 2: The flow has RESTRATIFIED at the beginning of this zone.

This flow region is INSIGNIFICANT in spatial extent and will be by-passed.

END OF MOD251: DIFFUSER PLUME IN CO-FLOW

** End of NEAR-FIELD REGION (NFR) **

The initial plume WIDTH values in the next far-field module will be
CORRECTED by a factor 1.58 to conserve the mass flux in the far-field!
The correction factor is quite large because of the small ambient velocity
relative to the strong mixing characteristics of the discharge!
This indicates localized RECIRCULATION REGIONS and internal hydraulic JUMPS.

BEGIN MOD241: BUOYANT AMBIENT SPREADING

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
13.70	.00	8.69	54.0	.185E+01	8.69	17.68	8.69	.00
63.02	.00	8.69	66.3	.151E+01	4.75	39.68	8.69	3.94
112.33	.00	8.69	72.8	.137E+01	3.66	56.55	8.69	5.03
161.65	.00	8.69	77.8	.129E+01	3.11	71.15	8.69	5.58
210.96	.00	8.69	82.2	.122E+01	2.77	84.34	8.69	5.92
260.27	.00	8.69	86.4	.116E+01	2.55	96.54	8.69	6.14
309.59	.00	8.69	90.6	.110E+01	2.39	107.98	8.69	6.30
358.90	.00	8.69	94.9	.105E+01	2.27	118.82	8.69	6.42
408.22	.00	8.69	99.5	.101E+01	2.19	129.17	8.69	6.50
457.54	.00	8.69	104.3	.959E+00	2.13	139.09	8.69	6.56
506.85	.00	8.69	109.4	.914E+00	2.09	148.66	8.69	6.60
556.16	.00	8.69	115.0	.870E+00	2.07	157.91	8.69	6.62
605.48	.00	8.69	120.9	.827E+00	2.06	166.88	8.69	6.63
654.79	.00	8.69	127.2	.786E+00	2.06	175.61	8.69	6.63
704.11	.00	8.69	134.0	.746E+00	2.07	184.11	8.69	6.62
753.42	.00	8.69	141.3	.708E+00	2.09	192.42	8.69	6.60
802.74	.00	8.69	149.1	.671E+00	2.11	200.53	8.69	6.58
852.05	.00	8.69	157.3	.636E+00	2.15	208.49	8.69	6.54
901.37	.00	8.69	166.1	.602E+00	2.19	216.29	8.69	6.50
950.68	.00	8.69	175.5	.570E+00	2.23	223.94	8.69	6.46
1000.00	.00	8.69	185.4	.539E+00	2.28	231.47	8.69	6.41

Cumulative travel time = 9950. sec

Simulation limit based on maximum specified distance = 1000.00 m.
This is the REGION OF INTEREST limitation.

END OF MOD241: BUOYANT AMBIENT SPREADING

CORMIX2: Submerged Multiport Diffuser Discharges End of Prediction File

5

ATTACHMENT 5

SOUTH END OF LAKE MICHIGAN
BIBLIOGRAPHY

ATTACHMENT 5
SOUTH END OF LAKE MICHIGAN BIBLIOGRAPHY

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6

ATTACHMENT 6

LAKE MICHIGAN BIOMONITORING PROGRAM
DATABASE AND SUMMARY REPORT

Lake Michigan Biomonitoring Program Database and Summary Report

Attachment 6 Volume II (Revised)

Prepared for:

Amoco Petroleum Products Refining Business Group
Whiting Business Unit
Whiting, Indiana

Prepared by:

Schafer & Associates
Golden, CO

and

The ADVENT Group, Inc.
Brentwood, TN

March 24, 1998

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APPENDICES

1.0 INTRODUCTION

Monitoring of near-shore Lake Michigan was continued following submittal to IDEM of the NPDES Permit Renewal Application for Amoco Oil Company in August 1994. Subsequent lake studies near Amoco's proposed multi-port diffuser were conducted to document lake characteristics and provide ecological data in support of a more complete description of existing ecological conditions. Physical, chemical, and biological samples were collected and analyzed from an area proposed as the site for the NPDES multiport diffuser. This monitoring program also provides data to address application requirements recently implemented with the adoption of the Great Lakes Initiative.

The monitoring program was designed to meet the following objectives:

1. Provide new information supplemental to the Permit Renewal Application (ADVENT 1994) with respect to characteristics of Lake Michigan at the proposed location of the multiport diffuser.
2. Document the natural variability of physical, chemical, and biological attributes of southern Lake Michigan at the location of the proposed multiport diffuser.
3. Support and augment the findings presented in Volume II NPDES Permit Renewal Application Mixing Zone Demonstration (ADVENT 1994).

2.0 STUDY SITES

Two study sites were chosen to represent Lake Michigan in the region of the proposed diffuser. Site S3500 was included in Attachment 5 Bioassessment Data Summary of Volume II (ADVENT 1994) and was retained as a monitoring study site. Site C3501 was established to investigate spatial variation in physical, chemical, and biological characteristics for southern Lake Michigan in the proposed diffuser area. A general description for each study site is given below and shown on Figure 2-1.

- S3500: Located approximately 3,500 feet from Amoco Outfall 001 along a magnetically corrected compass heading of approximately 39° at Longitude W87° 28.093' and Latitude N41° 40.976'. The S3500 site area is shown on Sheet 29 of National Oceanic and Atmospheric Administration (NOAA) Recreational Chart 14926 (January 20, 1990). Geographical Positioning System (GPS) coordinates shows the distance to be 0.27 nautical miles (1,640 feet) from the Amoco intake buoy.
- C3501: Located approximately 3,500 feet from Amoco Outfall 001 along a magnetically corrected compass heading of bearing of approximately 18° at Longitude W87° 28.349' and Latitude N41° 41.149'. Sites C3501 and S3500 are separated by a distance of approximately 1,500 feet along a bearing of 311.5 from magnetic North. The site C3500 area is shown on Sheet 29 of NOAA Recreational Map 14926 (January 20, 1990).

Positioning at the sites was accomplished by visual sightings on numerous landmarks for monitoring activities during May 1995. The coordinate position for site S3500 was established using GPS during November 1995. The coordinate position for site C3501 was established using GPS during October 1996. Measured total depth at both S3500 and C3501 were consistently between 28-30 feet.

2.1 Sample Site Selection

The locations of study sites S3500 and C3501 were selected because they met the following objectives:

- Represent a realistic location in Lake Michigan selected for installation of the proposed multiport diffuser.
- Representative of physical, chemical, and biological characteristics of the near-shore area for southern Lake Michigan west of Indiana Harbor Ship Canal.
- Are not influenced by existing discharges to or intakes from Lake Michigan.

The study site locations were selected following a study of the area, including (1) an intensive sonar survey to record bottom topography, (2) a diver-assisted visual survey to evaluate substrate homogeneity, and (3) evaluation of diver-collected sediment samples for visual inspection for homogeneity. Two study locations were identified specifically to expand the spatial scale of the data to better represent a large area of Lake Michigan.

2.2 Physical Description of General Study Area

Physical characteristics of the study site can be influenced by lake-wide patterns as well as shoreline related effects. Lake-wide currents, seasonal wind patterns, thermal convection and Coriolis forces that influence the deeper open waters of southern Lake Michigan also contribute to the physical conditions at C3501 and S3500. However, in the near shore zone (up to one mile from shore) the influence from localized storms in combination with shallow waters often greatly affect physical conditions in the study area because of the relative close proximity to the shoreline. For example, localized storms and wind currents may induce highly variable currents and turbulence in the shallow near-shore waters but have negligible effect on deeper lake-wide currents or stratification, which are influenced more by seasonal wind and storm patterns. Shoreline currents mainly follow the direction of the wind, and in the case of localized wind blowing toward the shore, the lake water will deflect to follow the shore contour (Saunders *et al.* 1976). Sites C3501 and S3500 are approximately 3,500 feet from shore in 28-30 feet of water. This region is in close proximity to the shoreline and reflects best a flooded beach. Winds and shoreline currents are likely more pronounced at the study site than for the outer near shore zone of southern Lake Michigan.

Winds and currents at the study area typically result in wave turbulence to the lake bottom and promote complete mixing throughout the water column at sites C3501 and S3500. The study site bottom is flat, with sediment dominated by small grain sand and some silt that is easily disturbed and re-suspended into the water column. Sediment material suspended in the water column have resulted in underwater visibility problems and low Secchi disk depths following periods of moderate to strong local winds. Stratification of the water column or formation of a thermocline is short lived, if present. Measurements at the study sites even during calm periods have shown uniform temperature, conductivity and dissolved oxygen profiles indicating complete mixing of the water column.

The trophic status of southern Lake Michigan has been classified as mesotrophic (Great Lakes Water Quality Board, 1977). This trophic status in intermediate between oligotrophic (clear water, low nutrient concentration, low biological productivity) and eutrophic (nutrient rich, highly productive). Measured densities and community composition for phytoplankton, zooplankton, chlorophyll *a* concentration, and water chemistry parameters from the water column at the study sites are consistent with the mesotrophic trophic status.

The benthos assemblage (organisms living on and in the sediments) is poorly developed. The uniform, sandy bottom composition and constant disturbance at the sediment surface from currents and wave action create an unstable and harsh habitat. The benthos includes midge larvae (Chironomidae), worms (Oligochaeta), snails (Mollusca), and small clams (Pelecypoda). The exotic Zebra mussel (*Dreissena polymorpha*) has been infrequently collected when the sample contains a piece of gravel or buried wood debris. The benthic organisms are subjected to continuous habitat disruption and abrasion from the bottom material and typically show a patchy distribution with low density and species richness. Ripples on the surface of the sediment that conform to the direction and velocity of induced wave action or currents are a characteristic feature of the bottom surface.

3.0 SEDIMENT

3.1 Sediment Collection Methods

Starting in November 1995, sediment samples at S3500 and C3501 were hand collected by a self-contained underwater breathing apparatus (SCUBA) diver using a coring device made of 2.5-inch-diameter by 8-inch-length (5 cm X 20 cm) polyvinyl chloride (PVC) pipe. The use of the coring device minimized loss of sampled material and maximized sampling efficiency. All samples were collected as 4-inch cores and capped underwater prior to extrusion from the bottom material.

A sampling grid was configured using depth contours and specifications for the proposed multiport diffuser mixing zone. The grid approach optimized sample collection for a maximum spatial area. The grid configuration used a benchmark point “B-0” that represented the longitudinal center of the 90-foot-long diffuser. Two 750-foot-long transects (B+ and B-) were established at right angles to the longitudinal axis of the diffuser, and a third (D+) as an extension of the diffuser axis (Figure 3-1). Sediment sample points were selected at 0, 25, 75, 125, 250, 500, and 750 feet from the center point of the diffuser (zero position being common to all three transects). Four additional 75-foot-long transects (A+, A-, C+, and C-) were established from each end of the proposed diffuser location and perpendicular to the diffuser axis. Sediment sample points were selected at 0, 25, and 75 feet from the diffuser along these four transects (site D+25 being common to zero position of the A+ and A- transects). A total of 28 sample positions were configured. Figure 3-1 shows, as an inset, the general location of S3500, the overall configuration of the sampling position matrix, and detailed sampling positions surrounding the proposed diffuser location.

For sediments, an extensive sediment characterization was conducted at S3500 during November 1995 when all 28 sample positions were used for sediment collection and analyses. A total of 72 sediment samples were collected at S3500 to evaluate sediment composition variation on three spatial scales: 0-6 inches apart, 3-6 feet apart and 25 feet apart, or greater.

Sediment samples collected to evaluate variation at 2 inches distance (5 cm) consisted of three replicate cores taken adjacent (i.e., PVC pipe touching) to each other. These adjacent cores were identified as replicates A, B, and C. Samples collected to evaluate variation on a scale of 3-6 feet apart (1.8 meters) consisted of three replicate cores (separated by approximately 3 feet each) taken at arm-length distance in random directions from the adjacent samples. These samples were identified as replicates D, E, and F. Four of 28 sample positions (A-25, B0, C+25 and B+750) were selected for collecting replicates A through F. Two replicate sediment samples collected approximately 1 meter apart were obtained at all 24 remaining sample positions shown in Figure 3-1. These samples were used to evaluate composition variability at 25 feet or greater distance, and to maximize spatial sampling for sediment composition analyses.

Statistical tests were used to independently determine significance for differences among the four intensively samples sites based on replicates A, B, and C (adjacent samples) and based on replicates D, E, and F (3-6 foot samples). Results of *t*-tests for statistical differences in mean percent composition of sand, silt, clay, and gravel between the 0-2 inch samples and the 3-6 feet samples showed the following:

1. No statistical differences were found among four sampling positions for mean percent composition of sand, silt, clay, and gravel based on sediment samples representing 6 square inches (98 cm^2) from each sample location.

2. No statistical differences were found among four sampling positions for mean percent composition of sand, silt, clay, and gravel based on samples representing approximately 6 square feet (0.55 m^2) from each sample location.

3. No statistical differences were observed in mean percent composition of sand, silt, clay, and gravel between samples representing 6 square inches (replicates A, B, and C) and samples representing 6 square feet (replicates D, E, and F) from four identical sample locations.

4. Sample data for replicates A through F collected from sites A-25, B0, C+25, and B+750 may be combined to represent an area of approximately 7.5×10^4 square feet to further refine the particle size composition characteristics for the sample site.

Differences in mean percent composition between the area represented by the 7.5×10^4 square foot area (24 sediment samples) and the remaining sample positions at S3500 (48 sediment samples) were evaluated using the statistical *t*-test for each of sand, silt, and clay and Wilcoxon's Rank Sum non-parametric test for gravel. Statistical test results showed no significant differences in mean percent composition for each of the particle size categories.

Based on the above findings, a description for the sediment composition was generated using the entire suite of sediment samples collected 3-6 feet apart from sites A-25, B0, C+25, and B+750, and all samples from the B- and B+ transect (34 sediment samples). Sediment samples collected from the D+ transect were not analyzed, and thus, not used to characterize the sediment composition at S3500.

The sediment survey indicated the number of sediment samples that could be reduced without loss of information due to the relative homogeneity of the sediment. However, a large spatial area was needed to adequately characterize the benthos community assemblage. During June 1996, sediment was collected from S3500 at 75, 125, 250, 500, and 750 feet along the B+, B-, and D transects and sites A0, B0, and C0 for a total of 18 sample positions. This configuration of sites resulted in a sampling area of approximately 12.9 acres (5.2 ha) spanning a distance of 1,500 feet. This same sampling scheme of 18 sample positions was repeated at C3501 and S3500 during October 1996 and April 1997.

Sediments material from each position was completely mixed and analyzed using ASTM Method D421 (sieve method for particles 75 microns (μ) diameter and larger) and ASTM Method D422-63 (hydrometer method for silts and clays). Size determinations were based on the Wentworth-Krumbein-Udden size classification for sediment grains.

3.2 Sediment Results

Sediments from the sample sites can be described as fine-grained sand with silts that exhibit an even spatial distribution. Analyses indicated that sand-sized particles (4.74 millimeters [mm] to 0.75 mm diameter) were the dominant component of the lake bottom material. Sand particles accounted for a mean composition of 76.3 percent with an observed range from 49.1 percent to 91.0 percent. Silt particles (0.074 mm to 0.005 mm diameter) were the next most common particle size and accounted for a mean of 21.2 percent composition with a range from 7.4 to 50.3 percent. Clay particles (less than 0.005 mm diameter) were a minor component of the sediment and contributed a mean of 2.3 percent composition and ranged from less than one to 4.8 percent. Gravel-sized particles occurred intermittently and were observed in 50 of 122 sediment samples. Gravel exhibited a mean composition of less than 1 (0.25) percent, with a maximum in one sample of 11.4 percent. Depending upon the size of the gravel, a single particle could account for up to 11.4 percent composition. Figures 3-2a through 3-2d show the composition data, including the mean percent abundance value and upper and lower 95 percent confidence limits for each particle size category. The percent composition data for each sediment sample is presented in Appendix A.

Changes in overall sediment composition among the November 1995, June and October 1996, and April 1997 sampling periods were not observed for either S3500 or C3501. Spatial trends in sediment composition were not observed among the 18 sampling positions at S3500 or C3501, as well as general trends between the study sites. The sediment information supports a characterization of the study area as a large flat zone of unconsolidated sand (76%) and silt (21%) conducive to disturbed surface materials and rippled surface topography with little to no slope in 28-30 feet of water.

4.0 BENTHOS

4.1 Collection Methods

Benthos collection methods were the same as for sediment described above. Additional core samples were collected for benthos analysis from S3500 during November 1995 at positions B+75, B-75, B+250, B-250, B+750, D+75, and D+500 for macroinvertebrate analyses. These positions were selected to give a good spatial representation of the sampling area. To maximize sampling efficiency, core samples collected during June 1996, October 1996, and April 1997 and used for sediment analyses were first evaluated for benthic organisms.

The November 1995 sampling scheme was altered to include 18 sediment sample positions (Figure 4-1) in subsequent sampling periods to verify the 1995 results that indicated a highly variable and patchy distribution for the benthos. Benthic macroinvertebrate core samples were obtained from all 18 sampling positions during June 1996, which further expanded the spatial range of the benthos samples. The June 1996 benthos samples showed a highly variable and patchy distribution of benthos organisms existed at S3500. Many of the June 1996 benthos samples contained one or zero organisms, and extrapolation of low density to commonly used units, such as number of organisms per meter, would be inappropriate and likely inaccurate. To better account for the variation in patchiness for the benthos, two sediment core samples were collected approximately 1 meter apart from each of the 18 sample positions and used for benthos evaluation during October 1996 and April 1997. This sampling scheme of 36 benthos samples was conducted at C3501 and S3500. All samples were transferred from the core device to sample storage containers and preserved with up to 10 milliliters (mL) of weak (3 percent) formalin solution prior to shipment for analysis.

4.2 Benthos Results

Benthos analyses consistently indicated an assemblage of low richness, density, and diversity with a patchy spatial distribution. A total of 169 benthos core samples were analyzed. The most abundant organisms were oligochaetes (Oligochaeta) followed by snails (Gastropoda), then fingernail clams and zebra mussels (Pelycepoda), and aquatic flies (Chironomidae). Leeches (Hirudinae), flatworms (Turbellaria) and amphipod crustaceans (Amphipoda) were occasionally observed. Oligochaetes accounted for 40.1 percent and snails accounted for 30.2 percent of the total organisms. Appendix B presents a taxonomic listing of observed organisms with richness, density, and measures of diversity for each benthos sample.

Organism richness was variable, but reflected an assemblage with generally low richness for benthos. Twenty-four of 169 samples had zero or one taxon present. A maximum richness of 10 taxa was recorded with a mean richness value of 3.5 taxa (Figure 4-2). The mean richness value is likely lower than actually present because many of the tubificid oligochaetes and aquatic flies were immature and identification to genus level was not possible. The maximum richness value of 10 taxa is still within a range that indicates low to moderate richness for benthos. Mature or large specimens of soft-bodied organisms, such as the oligochaetes and chironomids, were reported by the taxonomist to be rare. It is speculated that abrasion by the shifting sandy substrate resulting from wave disturbance may destroy larger soft-bodied organisms. Hard-bodied organisms, such as snails, clams, and amphipods that may be protected more from abrasion by shifting sands were observed in all sizes. The spatial relationship for richness indicated a patchy distribution with respect to the sampling grid.

Benthos density was highly variable among the samples. Benthos density was calculated as the number of organisms per cubic decimeter (organisms/dM^3) because it best reflects the size of the core sample (10 centimeters [cm] deep X 6.5 cm diameter). Mean benthos density was 50 organisms/dM^3 and ranged from zero to 344 organisms/dM^3. Figure 4-3 depicts the mean density and the array of density values for the benthos samples. Five benthos samples, each containing an abundance of very small fingernail clams, exhibited a density in excess of 200 organisms/dM^3. The spatial relationship for organism density indicated a patchy distribution with respect to the sampling grid.

Benthos assemblage diversity values indicated little diversity. Simpson's diversity values range from 1.0 for no diversity to 0.0 for maximum diversity. Simpson's Diversity values determined for each of the benthos samples ranged from 1.0 for samples with zero or one taxon present (no diversity) to 0.15 for the sample with 10 taxa. Mean Simpson's Diversity was 0.64. Shannon-Weiner Diversity values ranged from 0.0 for samples with zero organisms or one taxon present to 2.04 for the sample with 10 taxa. The mean Shannon-Weiner Diversity value was also 0.64. Simpson's Diversity values may provide a more meaningful range of density values for the benthos samples because calculation of Shannon-Weiner Diversity for assemblages that contained less than 10 taxa can be unreliable. Figure 4-4 shows the array of Simpson's Diversity values for the benthos samples.

The benthos community at C3501 and S3500 is highly variable and patchy with respect to spatial and temporal measures. With the exception of an overall increase in the total abundance of clams and snails observed during April 1997, large changes in overall benthos structure have not been observed for either S3500 or C3501. All data from November 1995 through April 1997 shows a patchy spatial distribution for benthos richness and benthos abundance during all sampling periods.

5.0 PHYTOPLANKTON

5.1 Collection Methods

A depth-integrated composite of the water column collected at position "B0" was used to obtain grab samples for phytoplankton analyses. The composite water sample was retained in a large bucket into which water was pumped from a submersible pump attached to a hose that was slowly lowered and raised from the water surface to 0.5 M above the bottom. The compositing bucket contained sufficient volume for grab samples consisting of a 1.0-liter (L) plastic bottle for phytoplankton, two 1.0-L amber plastic bottles for chlorophyll *a* analyses, and a full set of water chemistry sample bottles. The water column was again composited for replicate samples.

Three replicate phytoplankton grab samples were collected at S3500 during the May 1995, June 1996, October 1996, and April 1997 sampling periods. Three replicate phytoplankton grab samples were retained from C3501 during May 1995, October 1996, and April 1997. All samples were immediately preserved with weak Lugol's solution and properly stored until shipment for analysis.

5.2 Phytoplankton Results

The phytoplankton was moderately diverse and exhibited cell density values typical for oligotrophic to mildly mesotrophic lake conditions. Seven major groups of algae were represented and include the diatoms (Bacillariophyta), and the green algae (Chlorophyta), blue-green algae (Cyanophyta), yellow-green algae (Chrysophyta), euglenoids (Euglenophyta), dinoflagellates (Pyrrhophyta), and cryptomonads (Cryptophyta). Diatoms were the most common group, which accounted for a mean of 45 percent and range of 24 to 55 percent of total cell abundance. Among the soft algae groups (non-diatom taxa), yellow-green algae were the next most abundant with a mean of 27 percent of total cell abundance followed by a mean of 14 percent for green algae, and a mean of 8 percent for dinoflagellates. The blue-green were represented by 8 different taxa but accounted for a mean of 1.0 percent with a maximum of 5 percent of total cell abundance. A taxonomic listing for the soft algae and diatoms is presented in Appendix B. Table 5-1 presents values for minimum, maximum, and mean richness; cell density and diversity for the soft algae and diatoms; and total percent contribution for each of the major algae groups.

Richness for the soft algae ranged from 7 to 15 taxa with a mean of 10 taxa from a total of 35 taxa identified. The yellow-green algae *Dinobryon sociale* variety *americum*, the green algae complex *Chlorella/Chlorococcum humicola* and *Chlamydomonas* sp., and the dinoflagellate *Chroomonas nordstedtii* were the most abundant soft algae forms that demonstrated seasonal succession in the lake. *Dinobryon* and *Chlorella/Chlorococcum* were more abundant during spring and *Chlamydomonas* and *Chroomonas* tended to be more abundant during fall sampling periods.

Richness for the diatoms ranged from 26 to 55 taxa with a mean of 44 taxa from a total of 141 taxa identified. Diatom taxa commonly encountered include *Asterionella formosa*, *Diatoma tenuis* and the variety *elongatum*, several varieties of *Fragilaria capucina* and *Fragilaria construens*, species of the genus *Nitzschia*, *Stephanodiscus,* and *Cyclotella*. Many of the diatom taxa identified represent forms that typically occur as periphyton (attached to surfaces) that successfully persist in the water column as "tychoplankton" after detachment due to physical disturbance. Reports from project SCUBA divers of turbulence from wave action at the sediment surface, and the persistence of ripples on the lake bottom at the sampling locations attest to a constant resuspension of tychoplankton into the water column. Sediment material was always rippled and project SCUBA divers reported a shifting of surface sediment material from wave action during even the most calm sampling periods. Abundant tychoplanktonic forms observed in the samples include species from the genera *Diatoma*, *Fragilaria* and *Nitzschia, Synedra* and *Navicula.* Figure 5-1 shows the richness data and mean richness value for the diatom assemblage.

Total phytoplankton density ranged from 292 to 1,239 cells per milliliter (cells/mL) with a mean of 688 cells/mL. Diatoms accounted for a mean of 44.1 percent and exhibited a range of 26.3 to 55.3 percent of the total cell abundance. Figure 5-2 shows the soft algae, diatom, and total density values.

Diversity for the soft algae was moderate to low. Simpson's Diversity value ranged from 0.82 to a value of 0.19 on a scale of 1.0 for no diversity to zero for maximum diversity. The mean Simpson's Diversity value was 0.34. Shannon-Weiner Diversity values ranged from a low of 0.48 to 1.9 on a scale of zero for no diversity to a maximum of 2.71 for the highest richness observed (15 taxa) for the soft algae. It is common to focus more on the diatom assemblage diversity since this is typically the major component of the phytoplankton. The diatom assemblage exhibited much higher diversity values because of greater richness values and the large number of taxa with similar abundance. The diatom assemblage mean value for Simpson's Diversity was 0.10 with a range of 0.17 depicting the lowest diversity to 0.07 for the highest diversity. Shannon-Weiner Diversity values for the diatom assemblage ranged from 2.29 to 3.12 with a mean value of 2.83. The diatom assemblage diversity values are representative of moderate to high diversity for the number of taxa observed. Figure 5-3 depicts the Shannon-Weiner Diversity data and mean value for the diatom assemblage.

Expected seasonal patterns common to deeper waters were generally observed during the sampling period. A general successional pattern for stratified lakes show phytoplankton numbers to increase in spring due to nutrient replenishment from spring overturn, warmer temperatures, and longer daylight hours. Diatoms tend to dominate the spring assemblage. The total phytoplankton standing crop decreases during summer but can show a relative increase for blue-green algae in late summer until fall overturn. The fall period is characterized by a second pulse in diatom biomass before a general decrease in total phytoplankton standing crop during the winter ice season. During winter dominant forms generally include chryptomonads, mobile chrysophytes, and diatoms.

The distribution of mean phytoplankton density at the sampling locations for the major algae groups by sampling period is shown in Figure 5-4. With the exception of April 1997, the phytoplankton reflected the expected seasonal biomass pattern. Phytoplankton standing crop, especially for the diatoms, is generally higher in spring and fall than during summer. Diatoms showed the highest mean density with peaks during May of 1995 (spring) and October 1996 (fall). A typical shift from *Asterionella formosa,* species of *Diatoma,* and some centric diatoms (*Cyclotella* and *Stephanodiscus* species) during spring, to some centric diatoms and *Fragilaria* species showing dominance during the fall was observed. The high standing crop of chrysophytes (yellow-green algae) common to the winter months a residual high population could be reflected in the May 1995 and June 1996 spring samples. Lower chrysophyte abundance was present in the October 1996 fall sample. Total phytoplankton biomass was low in the April 1997 spring sample. The relative contribution of the chrysophytes to the phytoplankton assemblage in April 1997 was nearly identical to the May 1995 spring collection. Green algae showed a general increase in mean cell density during the warmer sampling periods of June 1996 and October 1996. It is possible the spring maxima may have occurred prior to the April 28, 1997 sampling period. However, in the nearshore and turbulent environment of the sampling locations a typical spring maxima and summer reduction in standing crop may have been masked by localized storm conditions. Subsequent sampling of the phytoplankton at the study sites during late spring and summer of 1997 revealed a general increase in total standing crop from a mean of 390 cells/mL on April 28, 1997 through the first week of August followed by a decline in phytoplankton standing crop by early September 1997 to levels similar to April 1997 (Figure 5-5).

6.0 ZOOPLANKTON

6.1 Zooplankton Collection Methods

Zooplankton samples were collected from the "B0" position of the sampling grid by vertical net tow. A 0.5-M-diameter net of 80-micron (μ) mesh with a length-to-opening ratio of 5.1 to 1 was used for all zooplankton samples. The net was equipped with a removable 80-μ-mesh plankton bucket that concentrated the collection and allowed easy transfer to sample containers. Vertical tows were made by slowly lowering the net to approximately 0.5 M above the lake bottom and slowly raising the net to the water surface. Three replicate samples consisting of a single tow each were collected from C3501 and S3500 during May 1995, October 1996, and April 1997. Three replicate samples from S3500 were collected during June 1996. The contents of the net were washed into the plankton bucket prior to sample container transfer and preservation with 3 percent formalin solution.

6.2 Zooplankton Results

The zooplankton assemblage consisted of 14 different taxa, which included rotifers (Rotifera) and cladocera and copepods that represented the Crustacea. Zooplankton richness, diversity, and total density values were low and consistent with the oligotrophic to mildly mesotrophic lake conditions implicated by the phytoplankton. Copepods were typically most abundant and accounted for a mean of 77.2 percent and range of 2.5 to 52 percent of total zooplankton abundance. Copepods observed included *Diacyclops bicuspidatus thomasi*, *Diaptomus* sp. and *Mesocyclops edax*. Rotifers accounted for a mean of 17.9 percent with a range of 46.1 to 97.1 percent of total abundance. The most common rotifer identified was *Asplanchna herricki*. Cladocera (*Bosmina longirostris* and *Daphnia*) accounted for a mean of 4.7 percent of the total zooplankton identified with a maximum of 11.6 percent of total abundance for a single sample. Zooplankton richness and diversity were low. Mean richness was 4.5 taxa with a range of 3 to 7 taxa (Figure 6-1). Actual richness may be slightly higher because the determination of richness values included immature specimens that could not be classified. However, based on the mature specimens in the samples at the time of collection, an increase in taxa from among the immature life stages would be still reflect low richness. Appendix B lists the zooplankton taxa and abundance data for all the collections.

Zooplankton density ranged from a low of 1,648 organisms/cubic meter (organisms/M^3) to a high of 7,914 organisms/M^3 with a mean density of 4,098.7 organisms/M^3 (Figure 6-2). The assemblage was highly variable with respect to abundance within each group among sample replicates. Total density values among replicates were usually similar although typically were higher during late summer and fall. Early summer and spring samples contained the highest number of copepod nauplii and copepodids that could not be identified to genus.

Variability in zooplankton richness and density was expected because of the many factors (currents, temperature, light, food availability, and predation) that influence zooplankton distribution and periods of reproduction. Because of the highly variable nature of zooplankton communities, especially in a physically turbulent habitat such as present at the sampling locations, the collection methods and analyses used here focus on the overall zooplankton assemblage. This approach maximizes the ability to detect composition differences at two locations at any one time.

Diversity values were determined with the inclusion immature specimens that could not be classified because it was believed the immature specimens likely represented a pulse bloom of a single taxon within the organism group. Simpson's Diversity values ranged from 0.9 to 0.29 on a scale of 1.0 for no diversity to 0.0 for maximum diversity. The mean Simpson's Diversity value for the zooplankton was 0.51. Shannon-Weiner Diversity values ranged from 0.24 depicting an assemblage with very low diversity to a value of 1.73 depicting moderate diversity for the number taxa typically represented by the zooplankton. Abundance values of nauplii copepods for all samples collected during April 1997 were well in excess of abundance values for other organisms and abundance values of nauplii observed in previous samples from the study sites. As a result, Simpson's Diversity and Shannon-Weiner Diversity values for the April 1997 zooplankton samples reflected the lowest diversity measures (Table 6.1).

7.0 CHLOROPHYLL *a*

7.1 Chlorophyll *a* Collection Methods

Chlorophyll *a* samples were obtained from a composite of the water column at position "B0" as described for phytoplankton in Section 5.0 above. To ensure that sufficient material was present for accurate chlorophyll determination, chlorophyll *a* samples consisted of two 1.0-L bottles that were combined and mixed prior to filtering and subsequent extraction for analysis.

Five replicate grab samples for chlorophyll *a* (consisting of two 1.0-L bottles each replicate) were retained for analyses during May 1995 from each of C3501 and S3500. Six replicate chlorophyll *a* samples were collected from S3500 during June 1996. Three replicate chlorophyll *a* samples were collected from C3501 and S3500 during October 1996 and April 1997. All chlorophyll *a* samples were immediately fixed with 1.0 mL of magnesium carbonate suspension and stored in the dark on ice until received by the analytical laboratory

7.2 Chlorophyll *a* Results

Chlorophyll *a* concentrations ranged from 0.32 to 2.5 mg/M^3 with a mean value of 1.0 mg/M^3. The low concentration values are consistent with oligotrophic to mild mesotrophic lake conditions as indicated by the phytoplankton and water chemistry samples collected from the study sites. It is important to note the chlorophyll *a* concentrations from the study sites are expressed as mg/M^3 rather than the more conventional mg/L unit of measure. Additionally, two liters of sample water per replicate were necessary to achieve a reliable analytical result. These two factors provide further evidence of the oligotrophic nature of the study sites. Table 7-1 shows the chlorophyll *a* concentration data for each study site and sampling period. A plot of the data against the mean concentration of 1.0 mg/M^3 is shown in Figure 7-1

8.0 WATER CHEMISTRY

8.1 Water Chemistry Collection Methods

Water chemistry samples were obtained from a composite of the water column at position "B0" as described for phytoplankton in Section 5.0 above. One composite water column grab sample was analyzed for water chemistry parameters at each of C3501 and S3500 during May 1995. Two replicate samples were retained for water chemistry analyses at S3500 during June 1996. Two replicate water chemistry samples were collected and averaged from C3501, and one water chemistry sample was retained for analysis from S3500 during October 1996. One water chemistry sample was collected for analysis at each of C3501 and S3500 during April 1997. Water chemistry data and the list of parameters measured for each of the samples listed above are identified in Appendix C. All water chemistry sample containers were stored in the dark on ice until received by the analytical laboratory.

8.2 Water Chemistry Results

Water chemistry parameter values determined by laboratory analyses for samples collected from the study sites are within values expected for southern Lake Michigan. Nitrogen and phosphorus related analytes exhibited some variability at concentrations near or below analytical detection limits indicating oligotrophic to mild mesotrophic nutrient conditions. A summary table of mean, minimum, and maximum values for the analytes is presented in Table 8-1.

9.0 *IN-SITU* WATER QUALITY

9.1 *In-situ* Water Quality Collection Methods

Depth profiled water quality determinations were measured *in-situ* using a Series III Datasonde probe and transmitter (Hydrolab Inc.). Parameters included pH (s.u.), conductivity (μmhos/cm), water temperature (°C), and dissolved oxygen (mg/L), which were measured at discrete levels of the water column from just above the lake bottom to the surface. Readings were taken at 3- or 5-foot intervals, depending upon surface wave height, and were measured over an average depth of 27 feet. Whenever possible, water quality determinations were made at each sample location every day monitoring activities were conducted.

9.2 *In-situ* Water Quality Results

Field determined water quality parameters indicate that complete mixing of the water column occurs at C3501 and S3500. Determinations of dissolved oxygen show profile of saturation or near saturation from the surface to the bottom. Differences in conductivity determinations from the surface to the bottom were absent or negligible. Temperature differences between the surface water and water at the lake sediment surface were typically less than two degrees (°C) and attributable to effects of ambient air near the top of the water column. In-situ water quality measurements are presented in Appendix C. Table 9-1 is a summary of the field determined water quality and shows the mean, minimum, and maximum values by depth for each of the parameters measured.

10.0 REFERENCES

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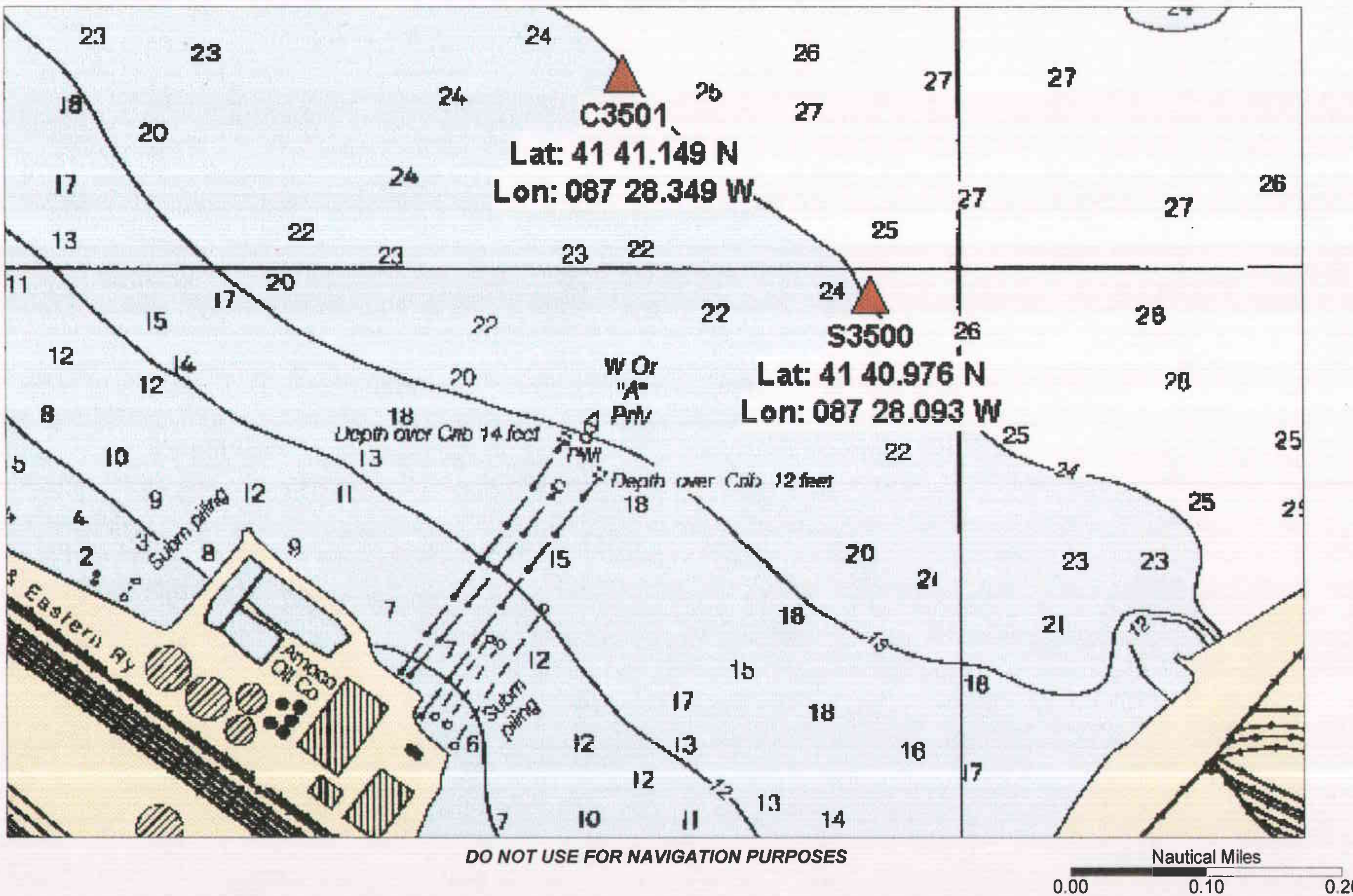
Figure 2-1
Proposed Diffuser Location (S3500) in Lake Michigan



From: Calumet and Indiana Harbors NOAA Chart 14929 (Jan. 20/90)

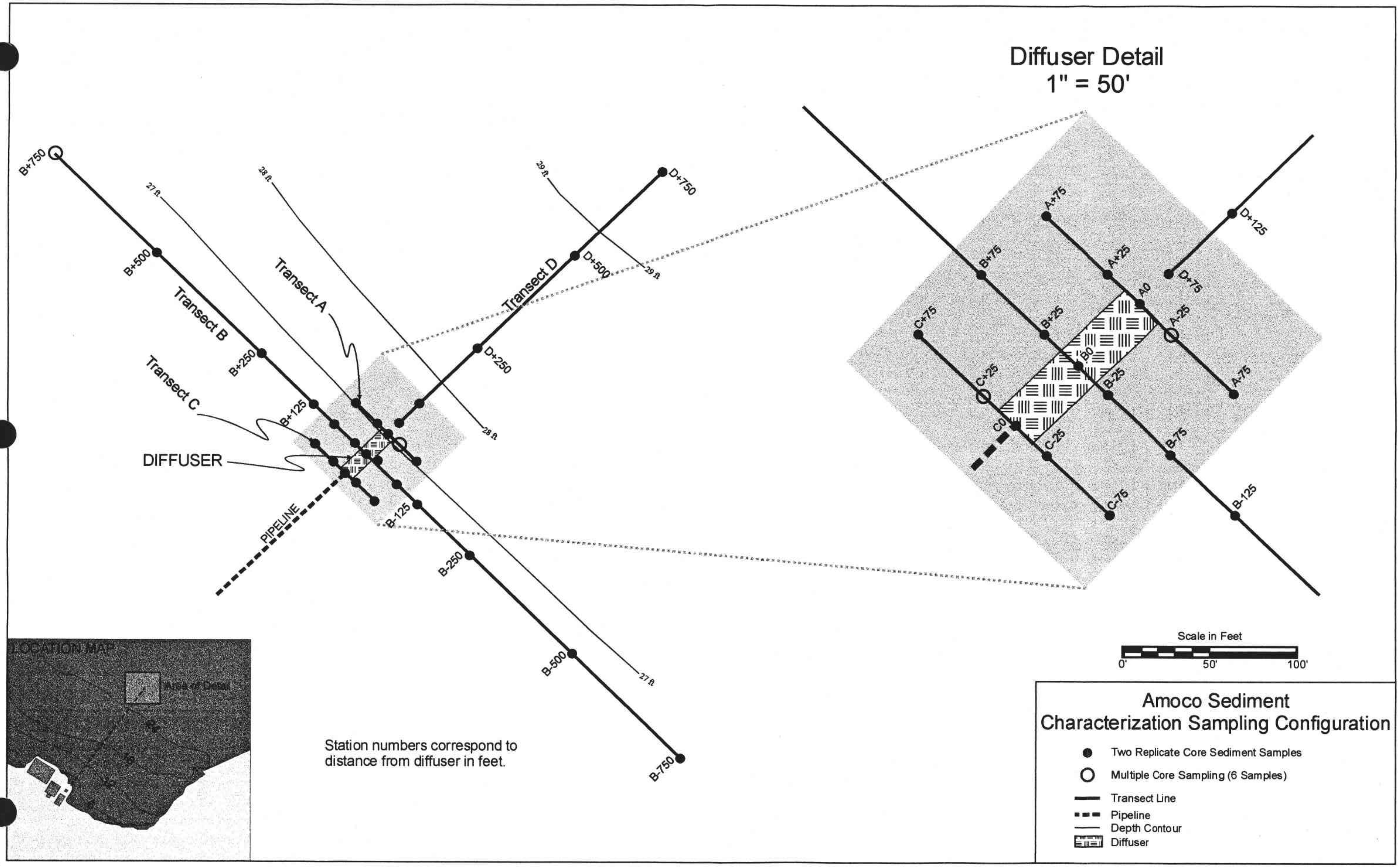
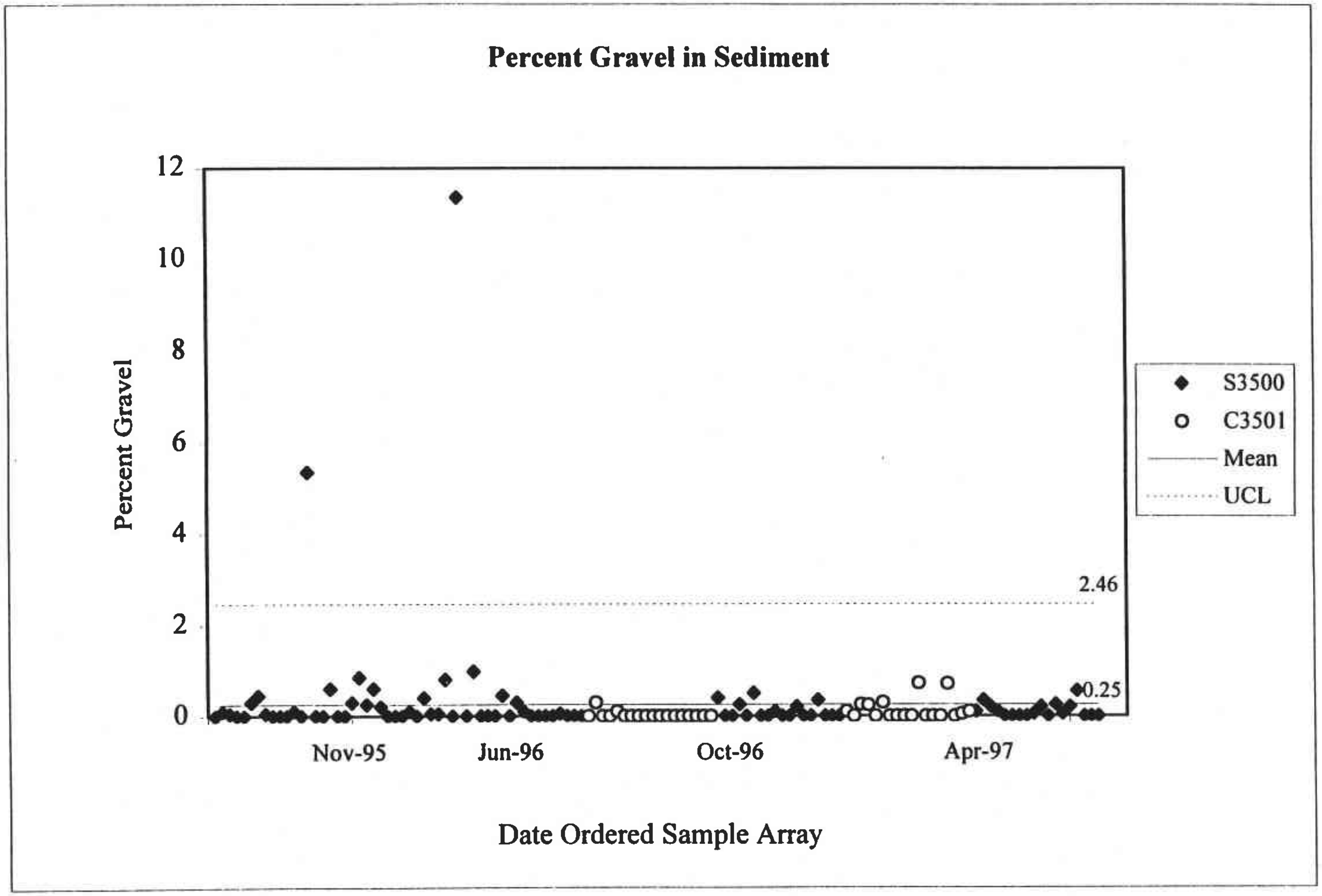


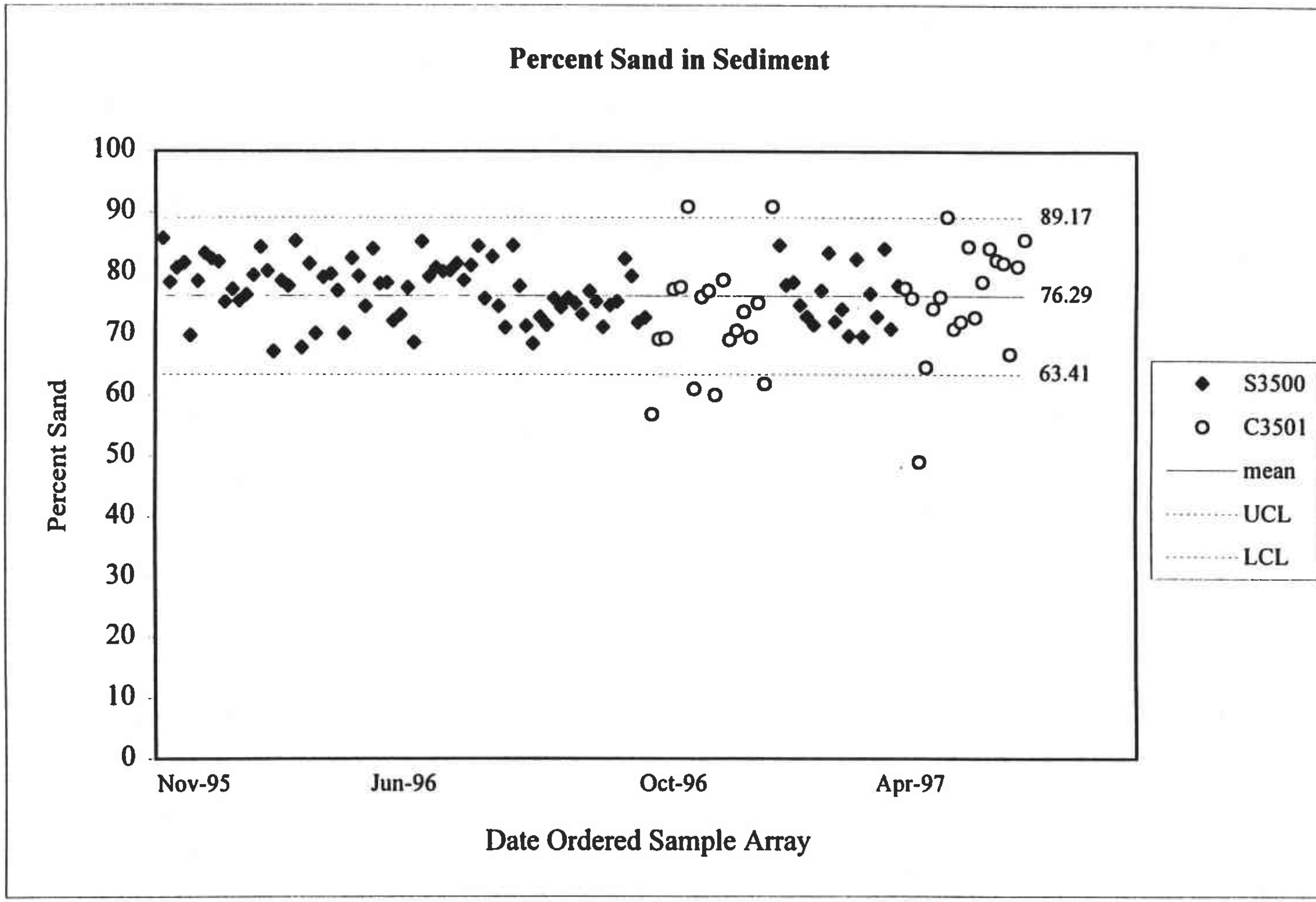
Figure 3-1. Amoco S3500 Sampling Site.

Figure 3-2a



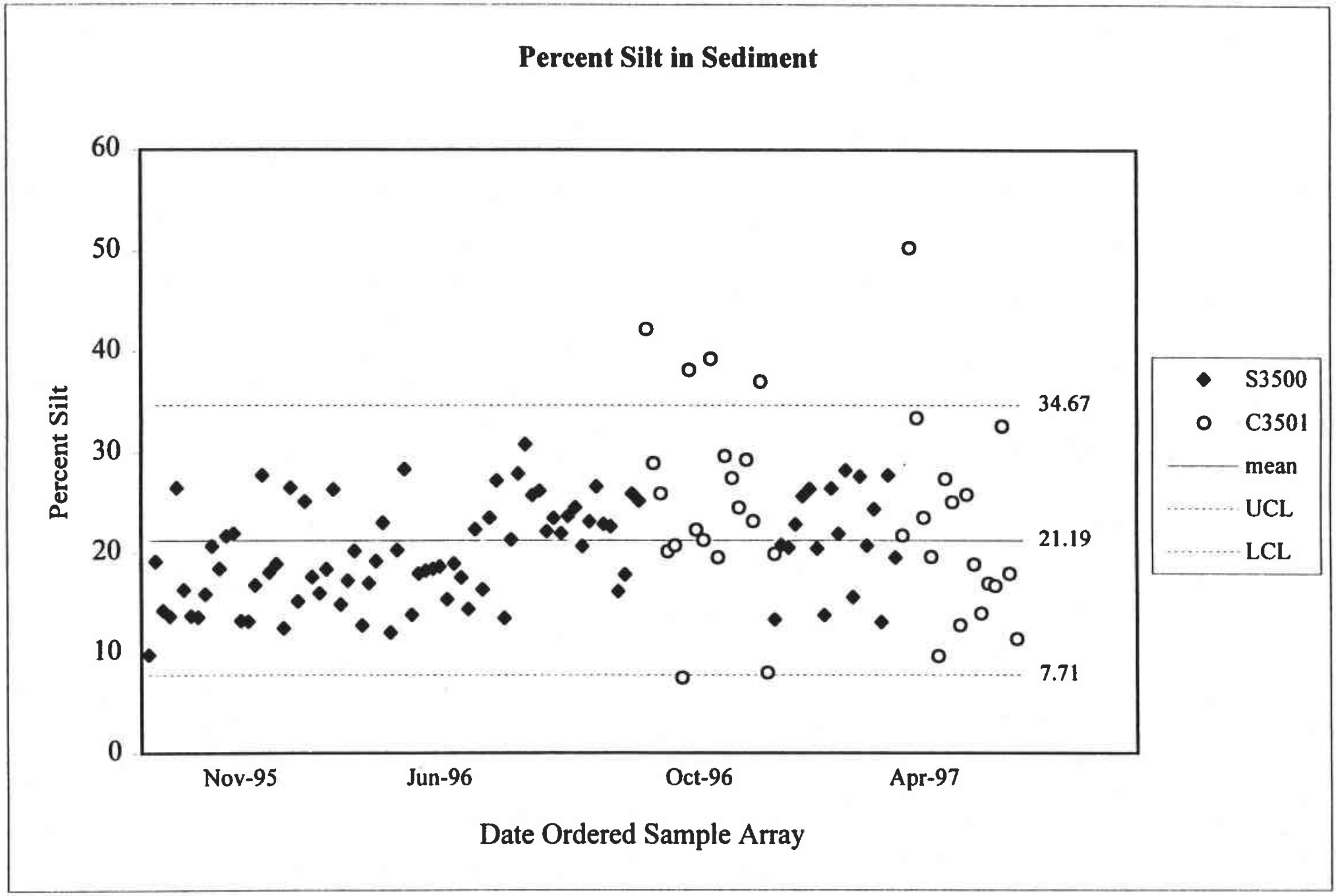
Percent Gravel in Sediment
12
10
8
6
4
2
0
Percent Gravel
2.46
0.25
Nov-95
Jun-96
Oct-96
Apr-97
Date Ordered Sample Array
S3500
C3501
Mean
UCL

Figure 3-2b



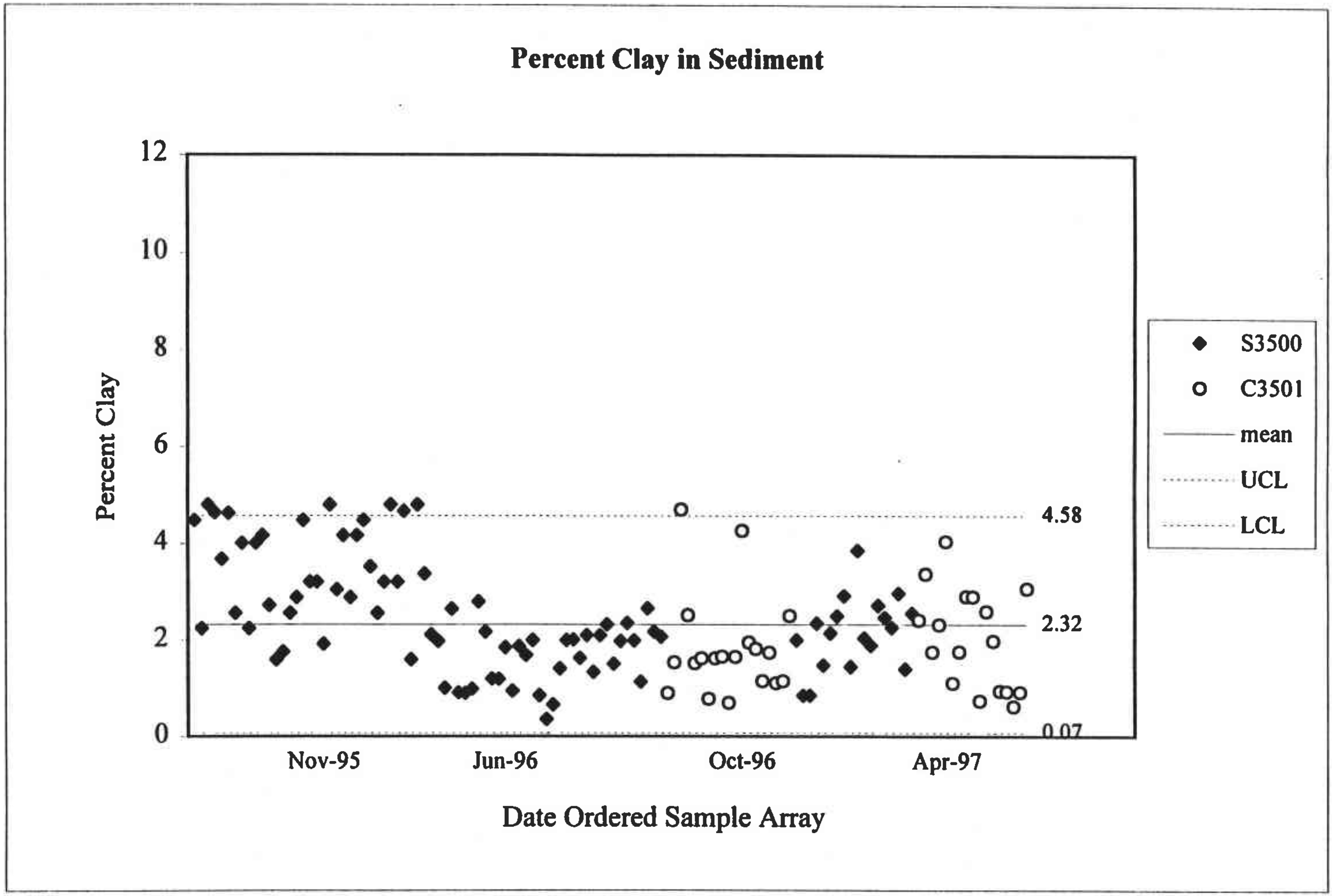
Percent Sand in Sediment
100
90
80
70
60
50
40
30
20
10
0
Percent Sand
89.17
76.29
63.41
Nov-95
Jun-96
Oct-96
Apr-97
Date Ordered Sample Array
S3500
C3501
mean
UCL
LCL

Figure 3-2c



Amoco\Task2\Dave2.xls\Figure 3-2c\1/13/98

Figure 3-2d


Percent Clay in Sediment
12
10
8
6
4
2
0
Percent Clay
4.58
2.32
0.07
Nov-95
Jun-96
Oct-96
Apr-97
Date Ordered Sample Array
S3500
C3501
mean
UCL
LCL

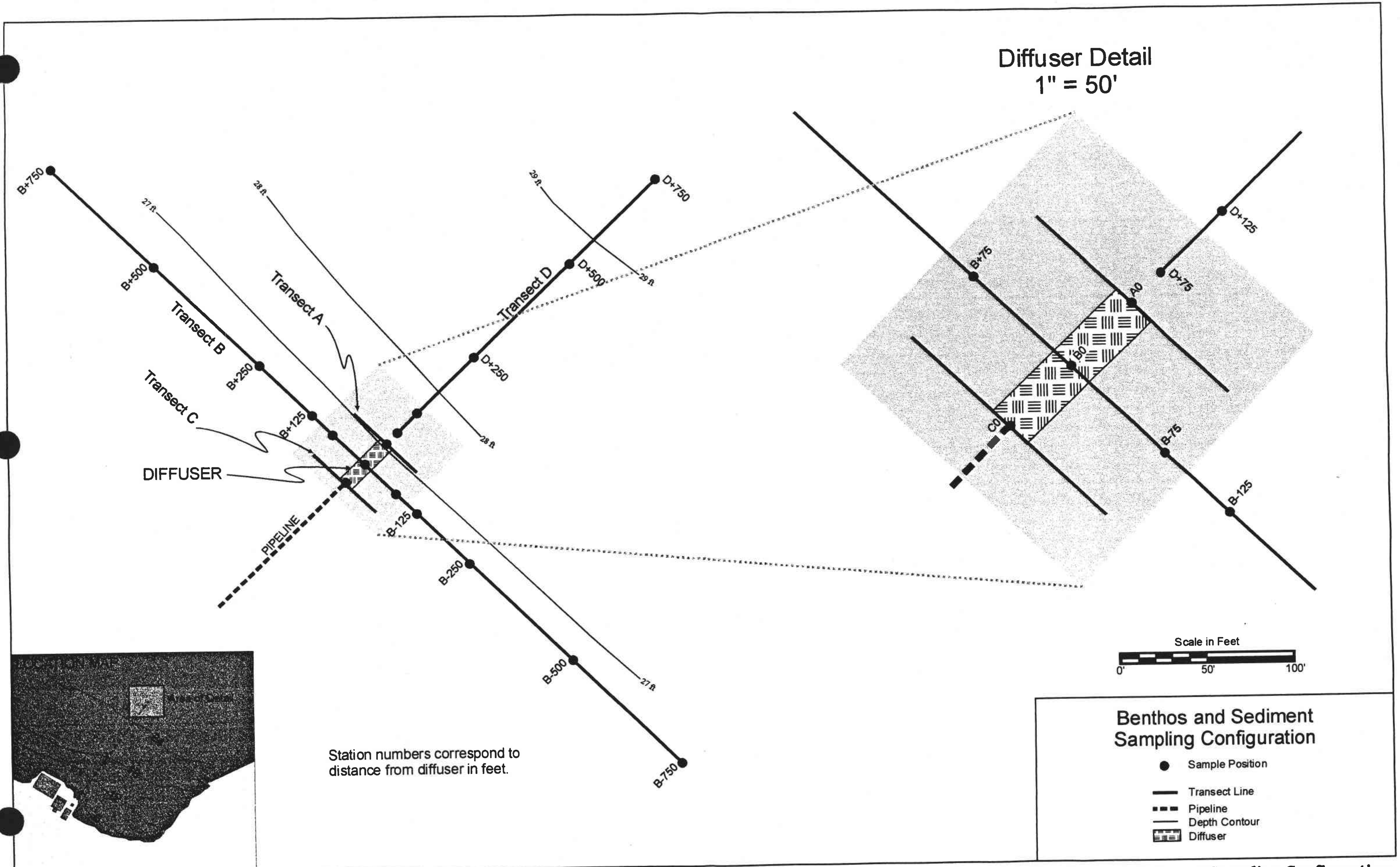
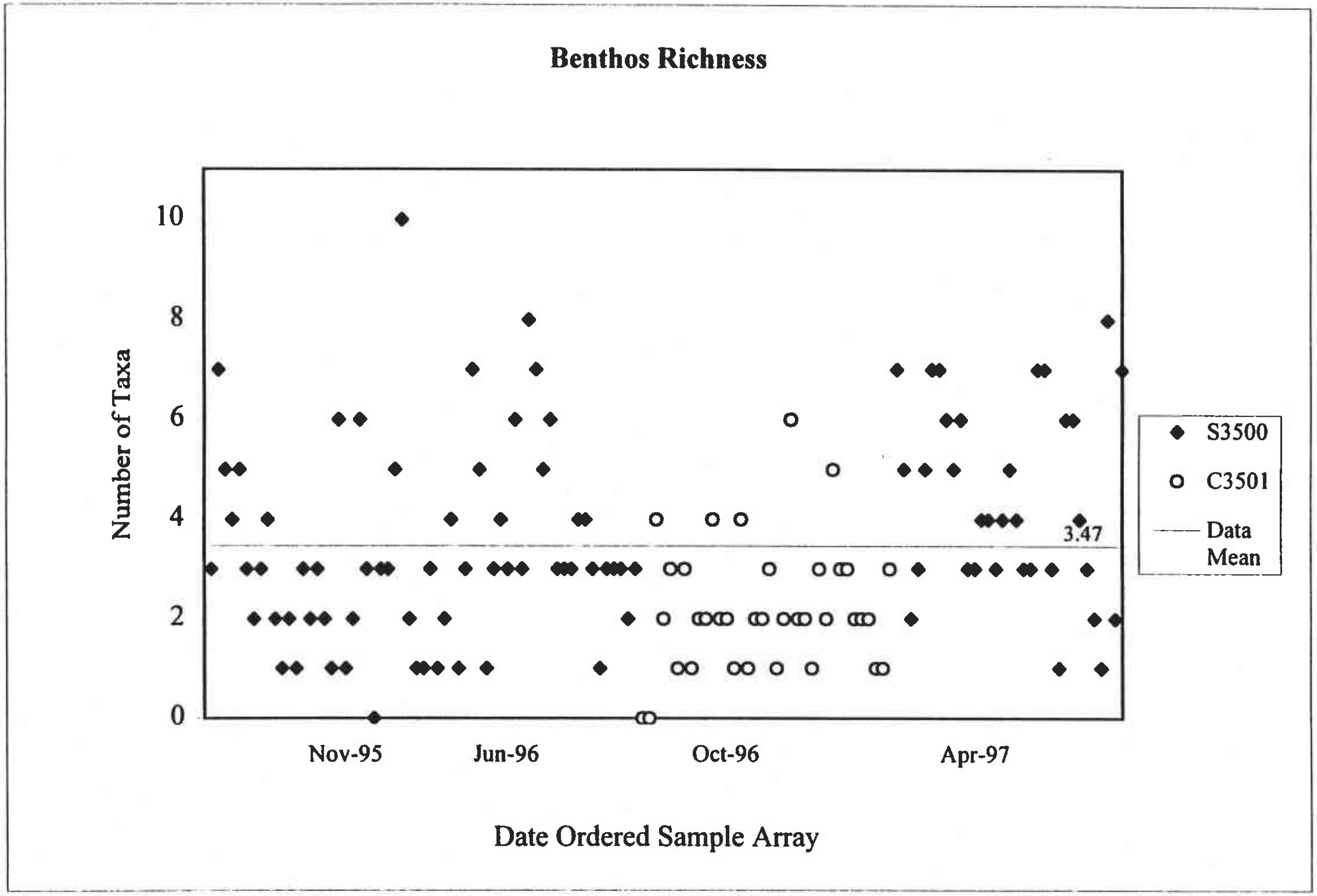


Figure 4-1. Benthos and Sediment Sampling Configuration.

Figure 4-2



Benthos Richness
10
8
6
4
2
0
Number of Taxa
3.47
Nov-95
Jun-96
Oct-96
Apr-97
Date Ordered Sample Array
S3500
C3501
Data Mean

Figure 4-3

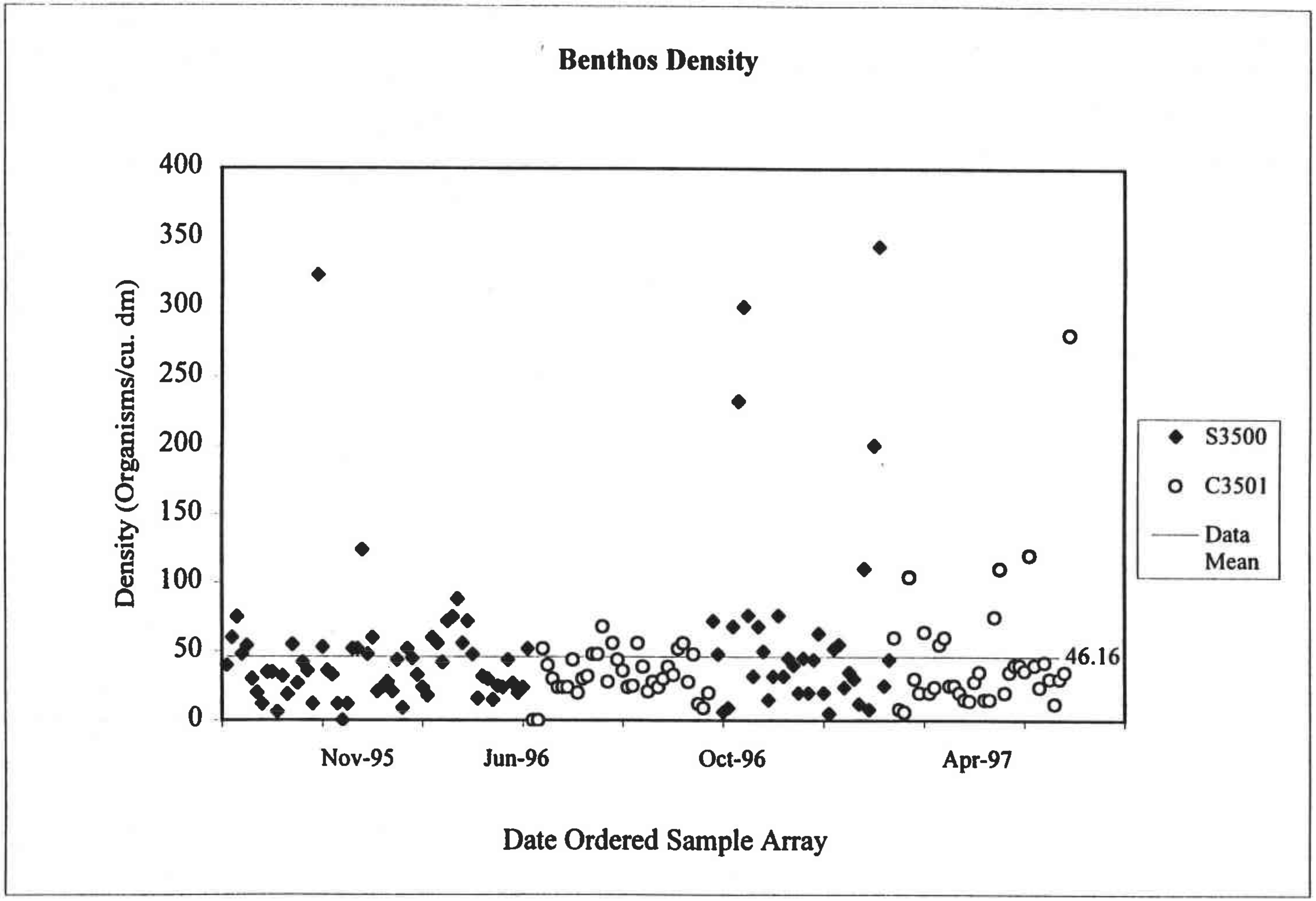

Benthos Density
Density (Organisms/cu. dm)
400
350
300
250
200
150
100
50
0
Nov-95
Jun-96
Oct-96
Apr-97
Date Ordered Sample Array
46.16
S3500
C3501
Data Mean

Figure 4-4

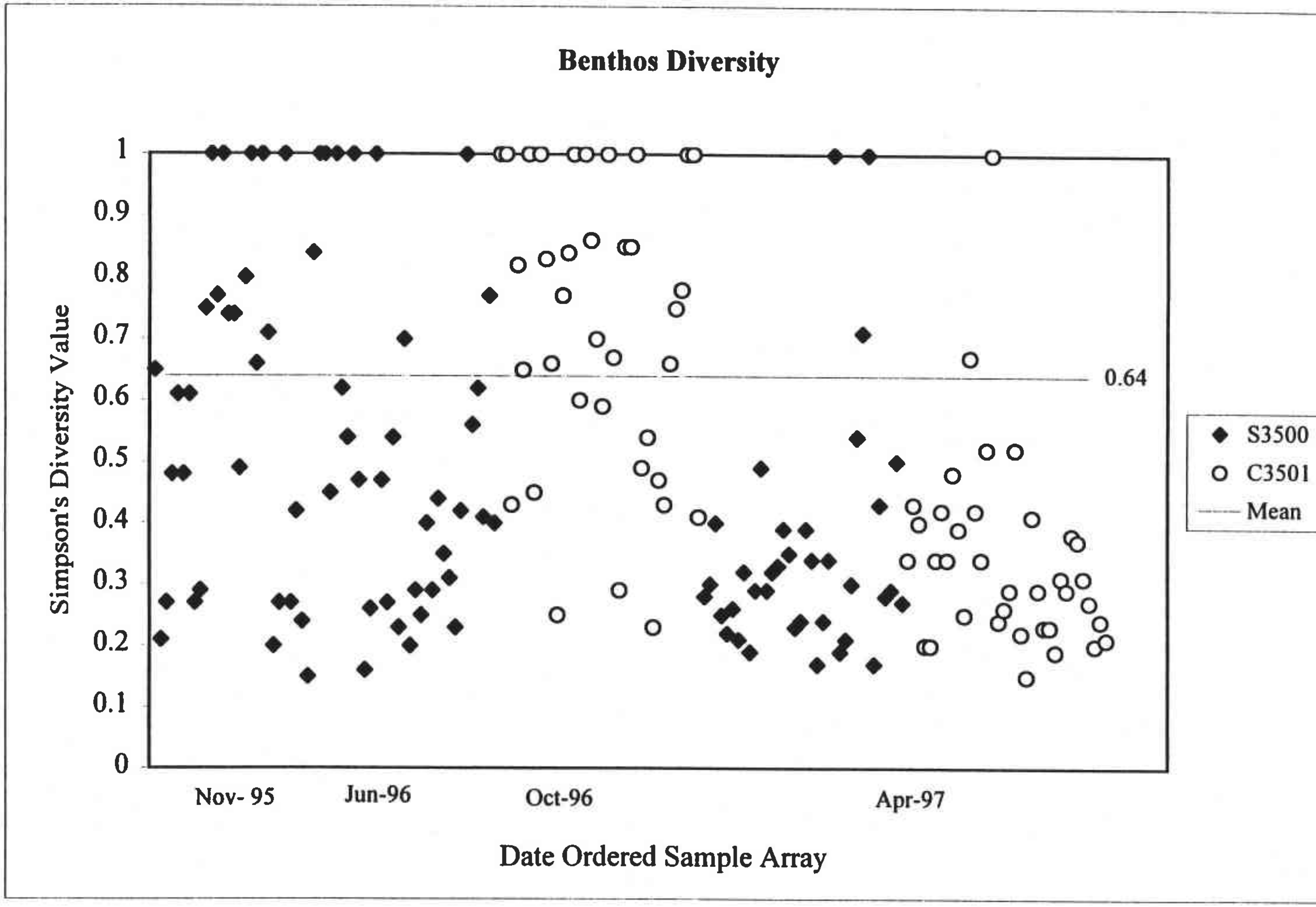

Benthos Diversity
Simpson's Diversity Value
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.64
Nov- 95
Jun-96
Oct-96
Apr-97
Date Ordered Sample Array
S3500
C3501
Mean

Figure 5-1

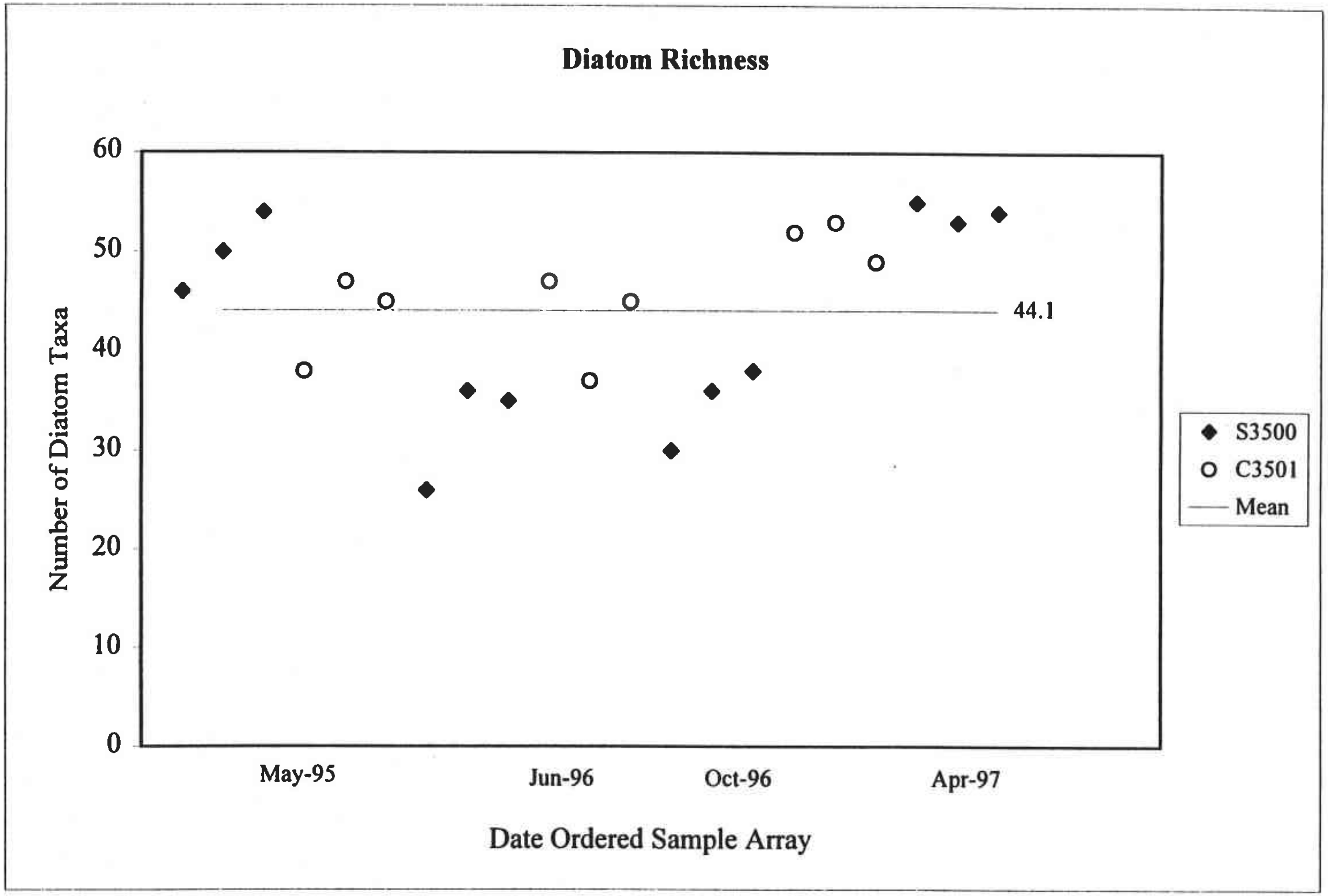
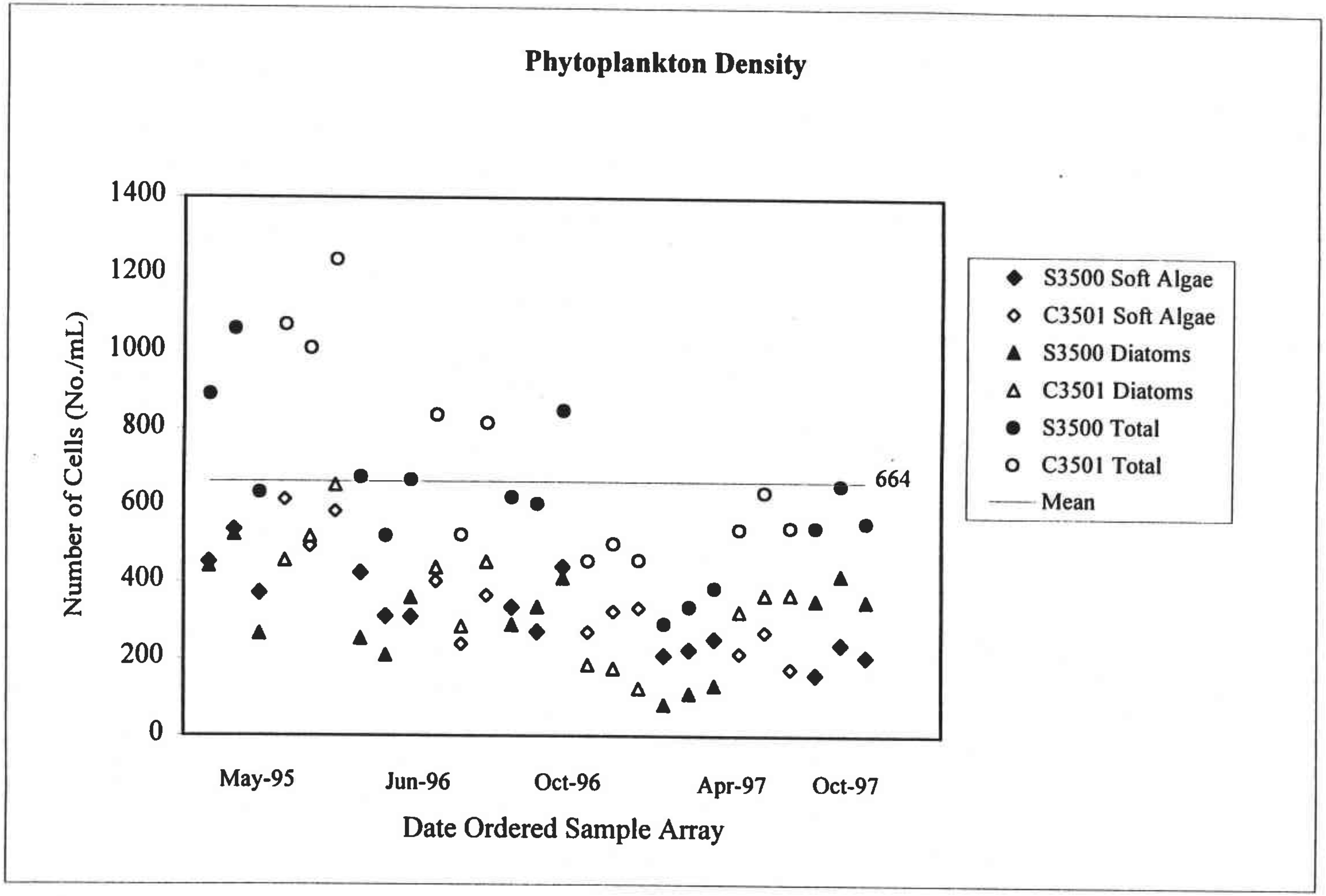
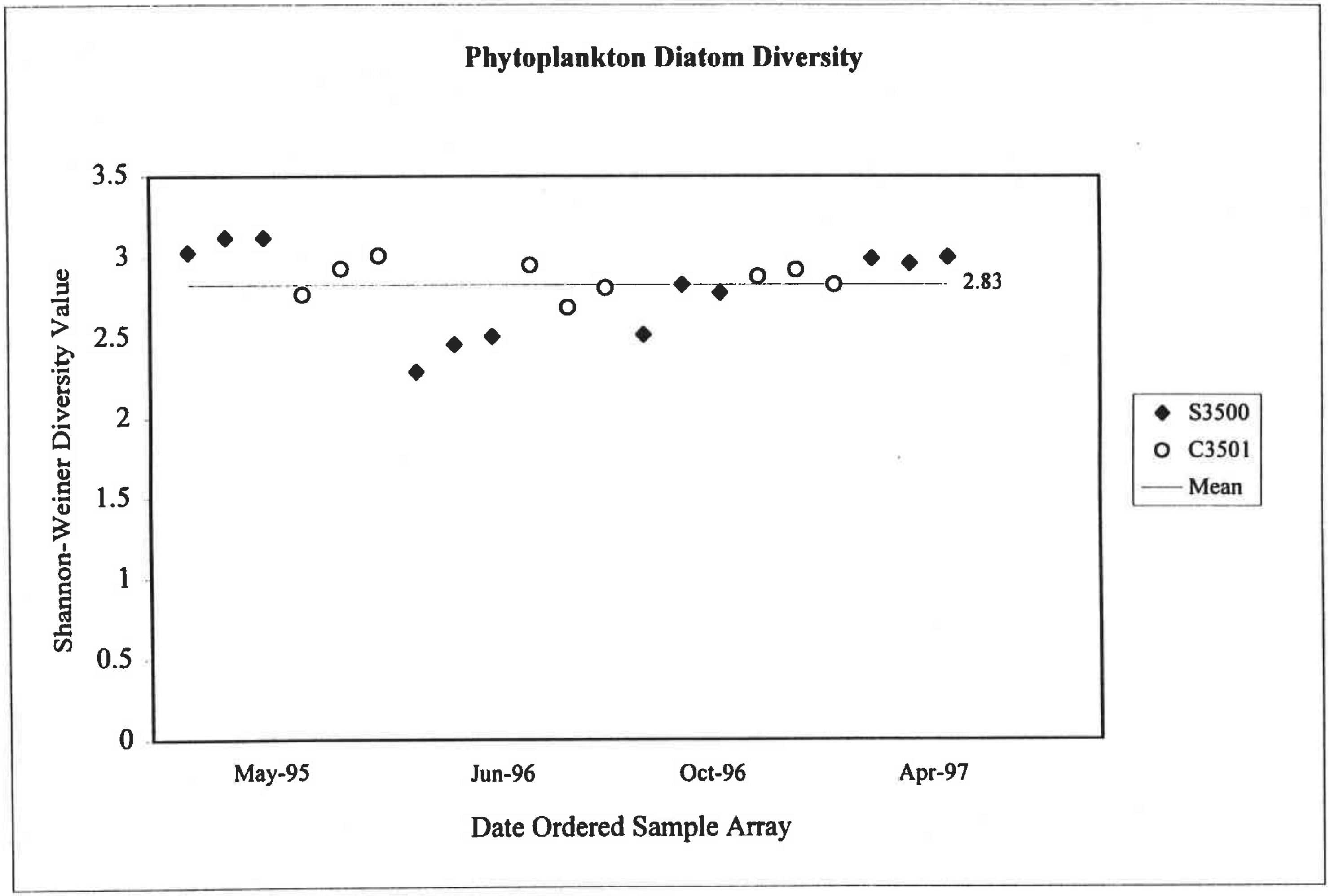

Diatom Richness
60
50
40
30
20
10
0
Number of Diatom Taxa
44.1
May-95
Jun-96
Oct-96
Apr-97
Date Ordered Sample Array
S3500
C3501
Mean

Figure 5-2



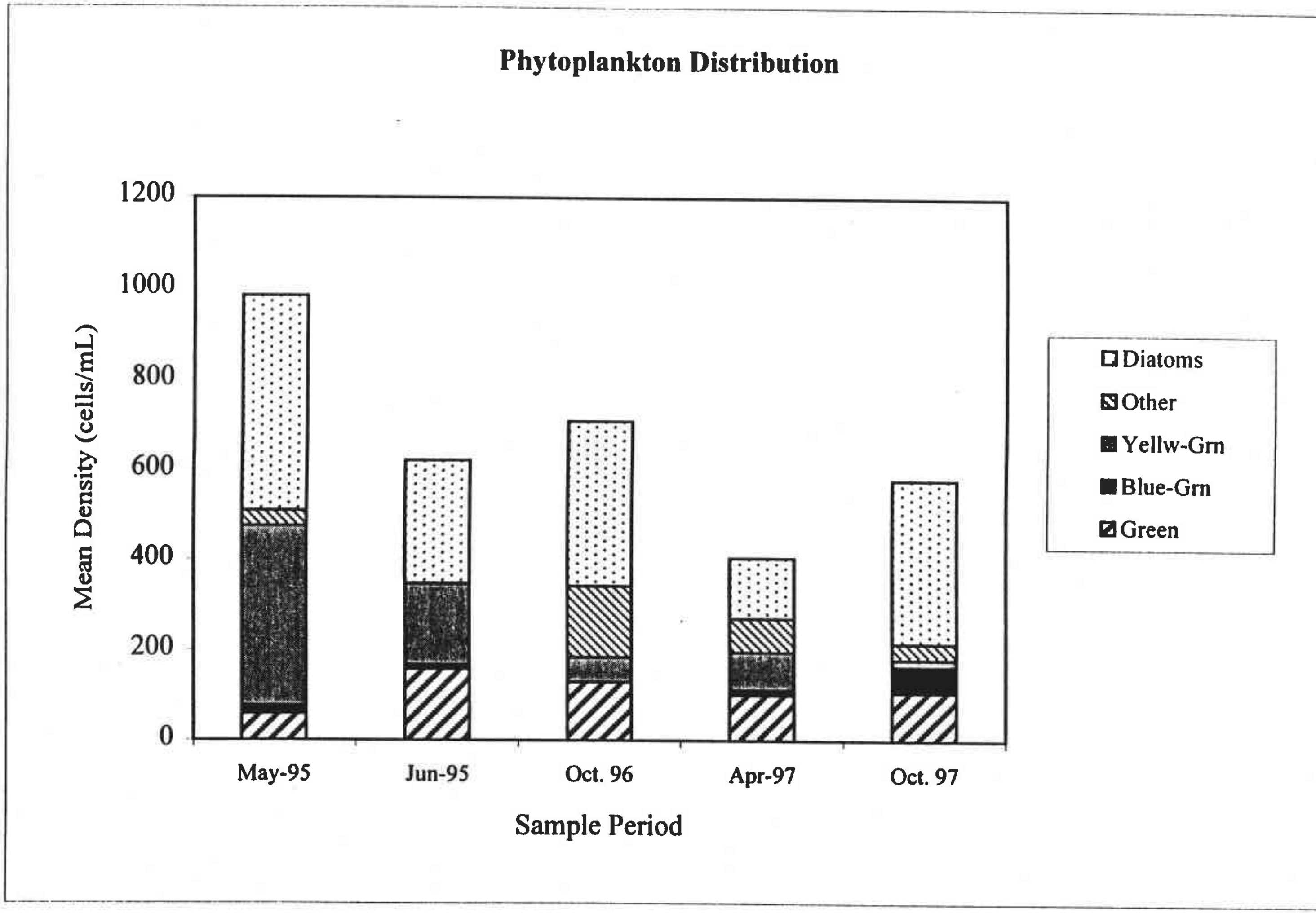
Phytoplankton Density
1400
1200
1000
800
600
400
200
0
Number of Cells (No./mL)
664
May-95
Jun-96
Oct-96
Apr-97
Oct-97
Date Ordered Sample Array
S3500 Soft Algae
C3501 Soft Algae
S3500 Diatoms
C3501 Diatoms
S3500 Total
C3501 Total
Mean

Figure 5-3



Phytoplankton Diatom Diversity
Shannon-Weiner Diversity Value
3.5
3
2.5
2
1.5
1
0.5
0
2.83
May-95
Jun-96
Oct-96
Apr-97
Date Ordered Sample Array
S3500
C3501
Mean

Figure 5-4



Phytoplankton Distribution
Mean Density (cells/mL)
1200
1000
800
600
400
200
0
May-95
Jun-95
Oct. 96
Apr-97
Oct. 97
Sample Period
Diatoms
Other
Yellw-Grn
Blue-Grn
Green

Figure 5-5

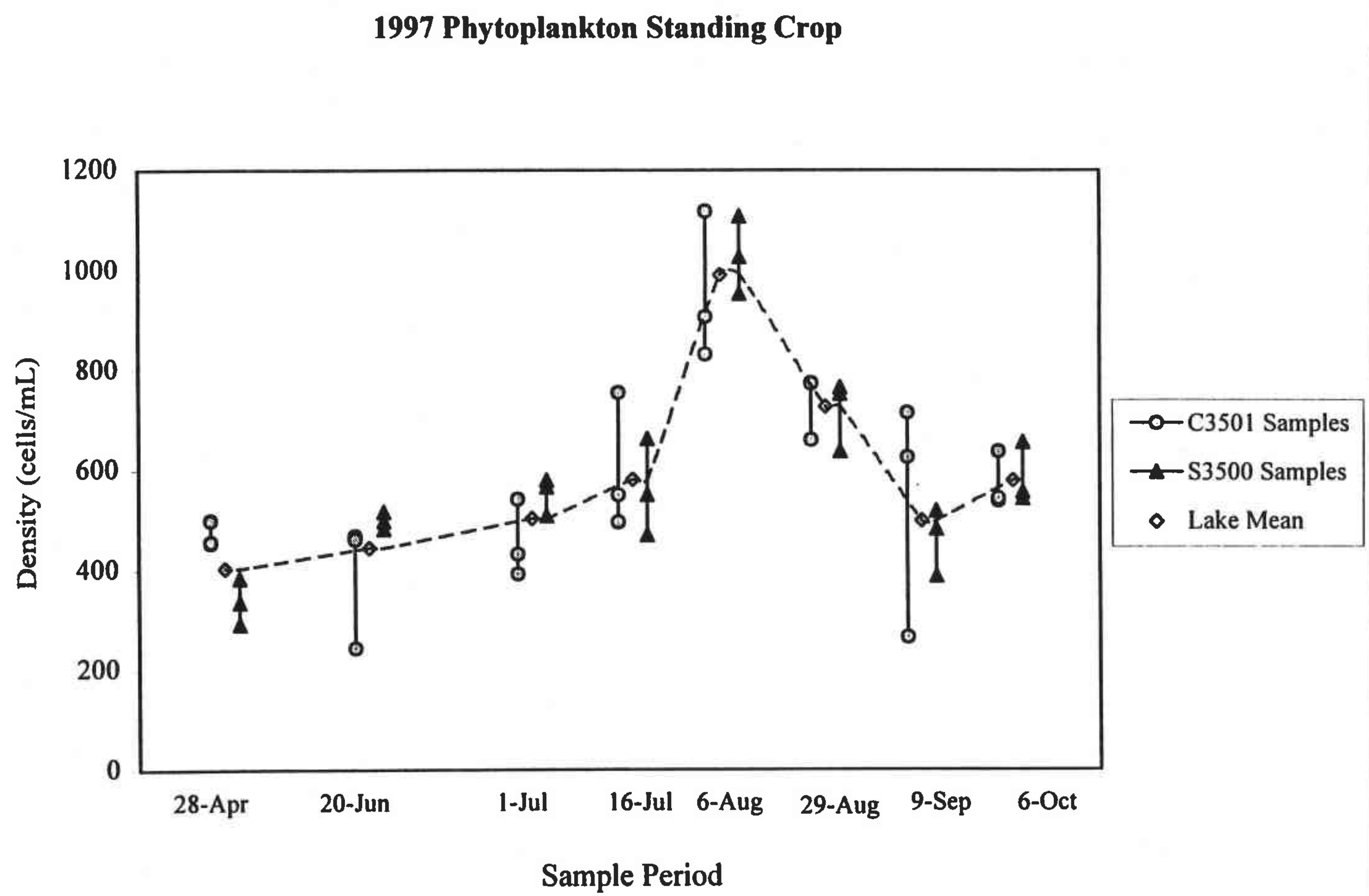

1997 Phytoplankton Standing Crop
Density (cells/mL)
0
200
400
600
800
1000
1200
28-Apr
20-Jun
1-Jul
16-Jul
6-Aug
29-Aug
9-Sep
6-Oct
Sample Period
C3501 Samples
S3500 Samples
Lake Mean

Figure 6-1

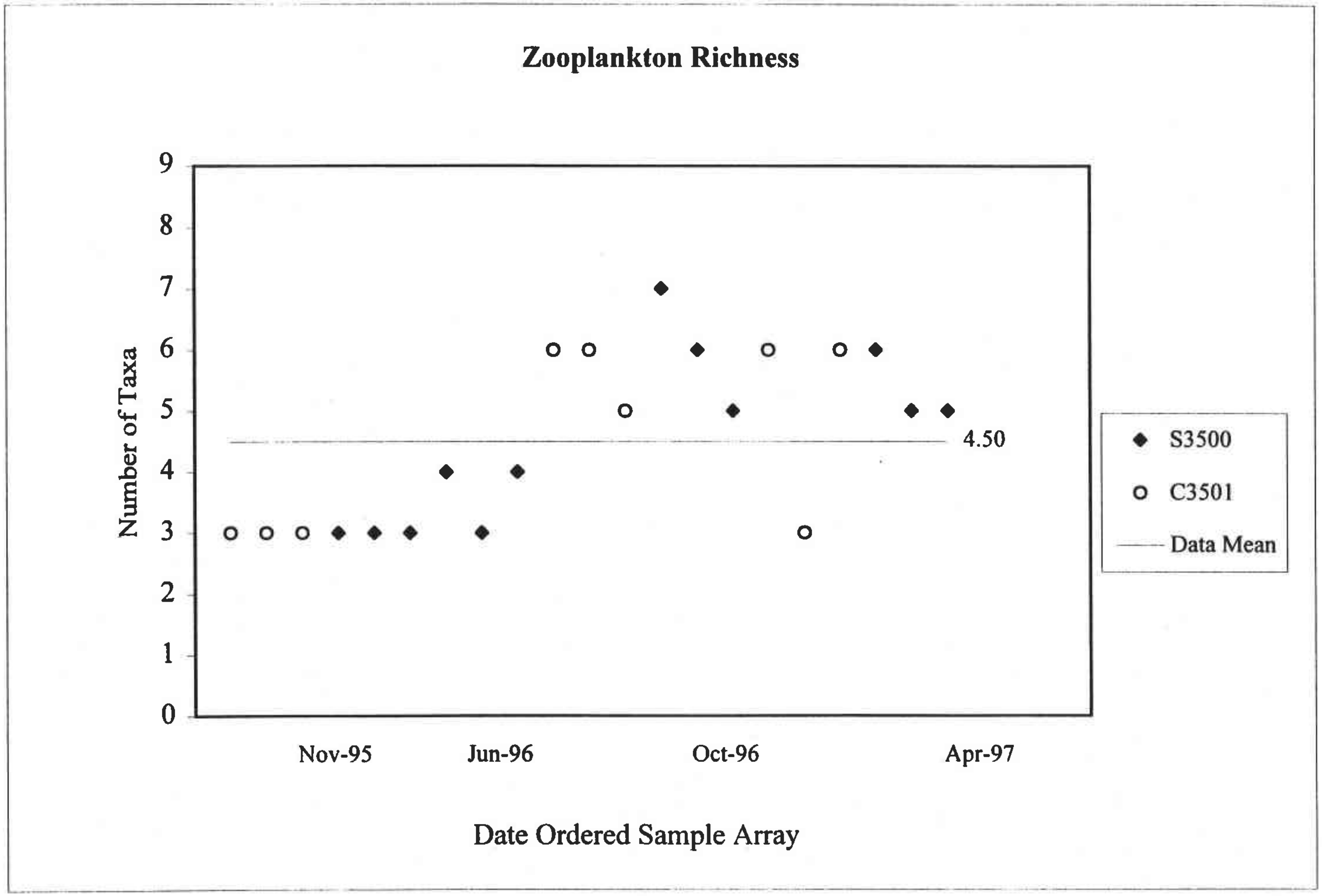

Zooplankton Richness
Number of Taxa
0
1
2
3
4
5
6
7
8
9
Nov-95
Jun-96
Oct-96
Apr-97
Date Ordered Sample Array
4.50
S3500
C3501
Data Mean

Figure 6-2

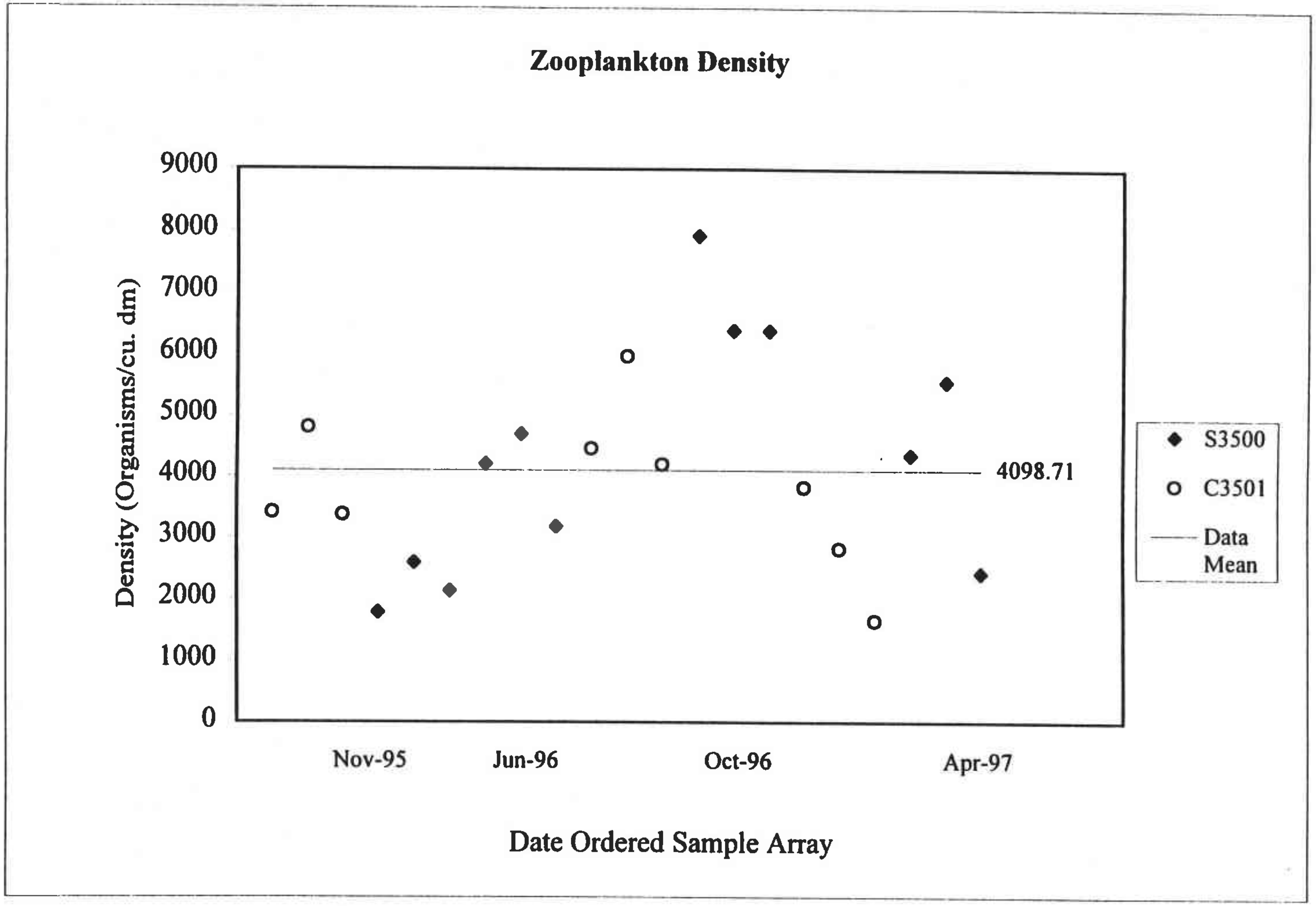
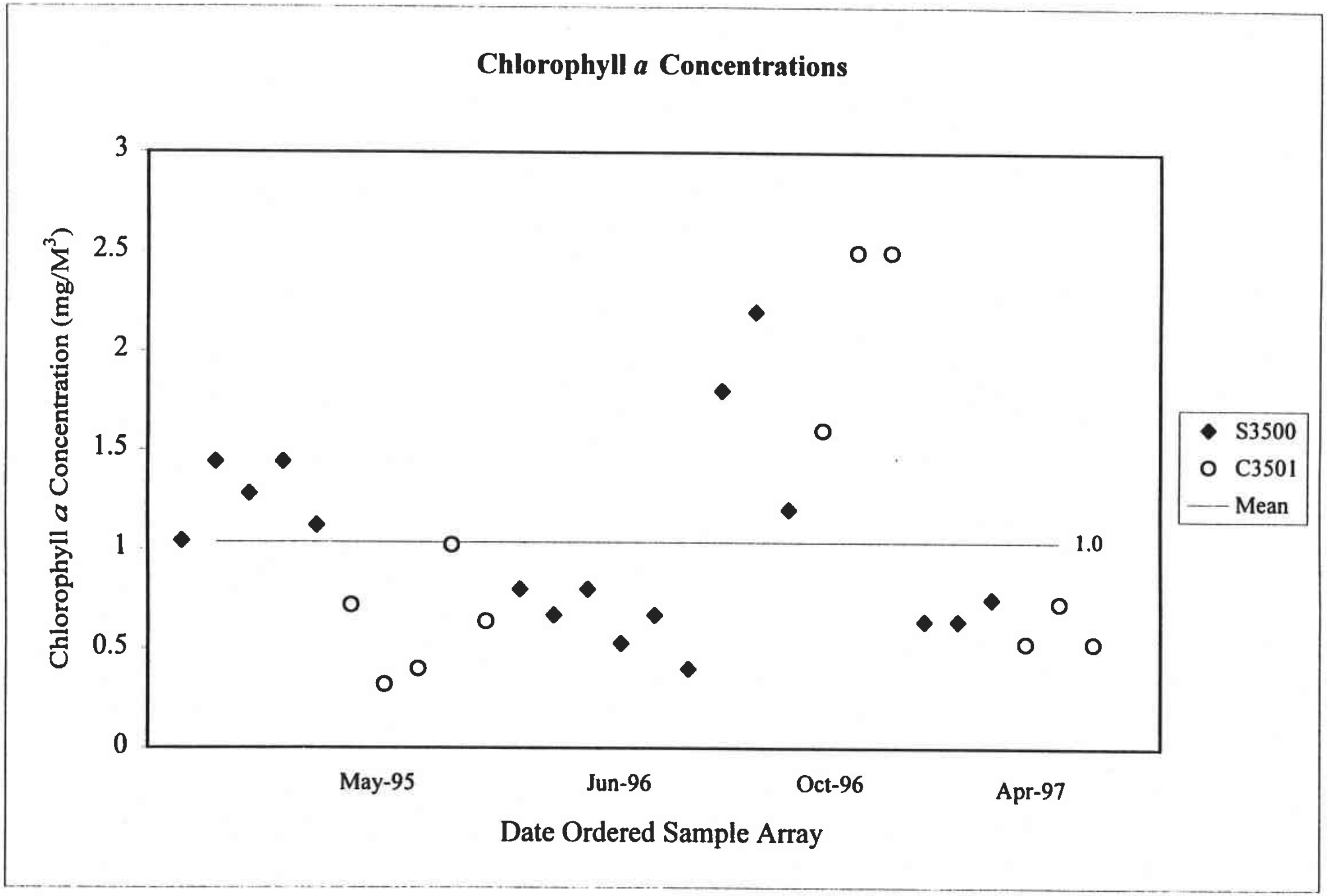

Zooplankton Density
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Density (Organisms/cu. dm)
4098.71
Nov-95
Jun-96
Oct-96
Apr-97
Date Ordered Sample Array
S3500
C3501
Data Mean

Figure 7-1



Chlorophyll *a* Concentrations
Chlorophyll *a* Concentration (mg/M^3)
3
2.5
2
1.5
1
0.5
0
1.0
May-95
Jun-96
Oct-96
Apr-97
Date Ordered Sample Array
S3500
C3501
Mean

Tables

Table 1-1
Amoco NPDES Permit Reapplication Biomonitoring Support Sampling Schedule

Siting Method	Visual Landmarks		GPS Positioning					
Location	S3500	C3501	S3500	S3500	C3501	S3500	C3501	S3500
Date	May-95		Nov-95	Jun-96	Oct-96		Apr-97	
Sample Type	Sampling Method							
Benthos	Dredge sample		Core sample	Core sample	Core sample		Core sample	
Phytoplankton	Grab sample		no sample	Grab sample	Grab sample		Grab sample	
Zooplankton	Net sample		no sample	Net sample	Net sample		Net sample	
Water Chemistry	Grab sample		no sample	Grab sample	Grab sample		Grab sample	
Hydrolab readings	Meter		Meter	Meter	Meter		Meter	
Sediment Size	Dredge sample		Core sample	Core sample	Core sample		Core sample	
Chlorophyll *a*	Grab sample		no sample	Grab sample	Grab sample		Grab sample	

Table 4-1
Lake Michigan Benthos Summary

Parameter	Units	Mean	Minimum	Maximum
Total Density	No./dM^3	50	0	344
Richness	Number	3	0	10
Simpson's Diversity	Value	0.64	0.15	0
Shannon-Weiner Diversity	Value	0.64	0	2.04
Percent Oligochaetes	Percent	50	0	100
Percent Snails	Percent	23.8	0	100
Percent Clams and Mussels	Percent	11.3	0	100
Percent Chironomids	Percent	14.5	0	100

Table 5-1
Lake Michigan Phytoplankton Summary

Parameter	Units	Mean	Minimum	Maximum
Total Density	No./mL	688	292	1239
Soft Algae				
Richness	Number	10	7	15
Density	No./mL	369	210	616
Simpson's Diversity	Value	0.33	0.82	0.19
Shannon-Weiner Diversity	Value	1.47	0.48	1.9
Percent Diatoms	Percent	43.4	21.1	55.3
Percent Green Algae	Percent	14	2.1	33.8
Percent Yellow-Green Algae	Percent	27	5.4	53.7
Percent Dinoflagellates	Percent	8.3	0	23.9
Percent Blue-Green Algae	Percent	1.2	0	5.0
Diatoms				
Richness	Number	44	26	55
Density	No./mL	319	82	654
Simpson's Diversity	Value	0.1	0.17	0.07
Shannon-Weiner Diversity	Value	2.83	2.29	3.12

Table 6.1
Lake Michigan Zooplankton Summary

Parameter	Units	Mean	Minimum	Maximum
Total Density	No./M^3	4,098.70	1,648	7,914
Richness	Number	6.1	4	8
Simpson's Diversity	Value	5.1	0.9	0.3
Shannon-Weiner Diversity	Value	1.0	0.2	1.7
Percent Rotifers	Percent	18	2.6	51.5
Percent Cladocera	Percent	4.8	0.0	11.6
Percent Copepods	Percent	77.3	46.2	97.1

Table 7.1
Chlorophyll *a* Determinations (mg/M^3)

Date	May-95		Jun-96	Oct-96		Apr-97	
Location	C3501	S3500	S3500	C3501	S3500	C3501	S3500
Replicate 1	0.72	1.04	0.8	1.6	1.8	0.64	0.53
Replicate 2	0.32	1.44	0.67	2.5	2.2	0.64	0.73
Replicate 3	0.4	1.28	0.8	2.5	1.2	0.75	0.53
Replicate 4	1.02	1.44	0.53	none	none	none	none
Replicate 5	0.64	1.12	0.67	none	none	none	none
Replicate 6	none	none	0.4	none	none	none	none

Table 8-1
Lake Michigan Water Chemistry Constituents

Parameter	Units	Method	Mean	Min.	Max.	n Samples
pH	s.u.	9040A	7.82	6.90	8.50	6
Total Suspended Solids (TSS)	mg/L	EPA160.2	1.64	0.90	3.00	8
Total Dissolved Solids (TDS)	mg/L	EPA160.1	172.00	140.00	198.00	8
Alkalinity as $CaCO_3$	mg/L	EPA310.2	110.00	110.00	110.00	2
Chloride	mg/L	2951	14.30	12.50	17.00	8
Total Organic Carbon (TOC)	mg/L	EPA415.1	6.79	2.50	20.00	8
Hardness as $CaCO_3$	mg/L	EPA130.2	150.38	133.00	160.00	8
Total Kjeldahl Nitrogen (TKN)	mg/L	EPA351.1	0.77	0.40	1.90	6
Nitrate/Nitrite	mg/L	9200	0.45	0.09	1.50	8
Total Nitrogen	mg/L	Calc.	1.65	1.56	1.74	2
Total Phosphorus	mg/L	EPA365.4	0.08	0.01	0.20	8
Ortho-Phosphorus	mg/L	EPA365.2	0.06	0.01	0.20	8
Silica	mg/L	6010	0.57	0.38	0.70	8
Sulfate	mg/L	EPA375.4	25.50	25.00	26.00	2
Total Calcium	mg/L	EPA215.1	69.50	54.00	85.00	2
Total Magnesium	mg/L	EPA242.1	12.00	12.00	12.00	2
Total Sodium	mg/L	EPA273.1	7.35	7.00	7.70	2
Total Potassium	mg/L	EPA258.1	1.80	0.30	3.30	2

Table 9-1
In-Situ Water Quality Summary

	Dissolved Oxygen (mg/L)				Temperature (C)				Conductivity (umhos/cm)				pH (s.u.)			
Depth (ft)	Min.	Mean	Max.	n = [1]	Min.	Mean	Max.	n =	Min.	Mean	Max.	n =	Min.	Mean	Max.	n =
surface	9.6	11.1	12.7	14	8.5	13.1	15.1	14	289	300.3	318	14	7.4	8.1	8.2	14
2 to 3	9.6	10.9	12.7	11	8.5	13.0	15.1	10	286	301.5	317	10	7.4	8.0	8.2	10
5 to 6	9.6	11.1	12.6	14	8.5	13.0	15.0	14	287	298.6	315	14	7.3	8.1	8.2	14
8 to 9	9.6	10.9	12.6	11	8.4	12.5	14.7	11	290	297.8	306	11	7.3	8.0	8.2	11
11 to 12	9.5	11.2	13.3	14	8.2	12.6	14.5	14	289	296.8	305	14	7.2	8.1	8.2	14
14 to 15	9.5	11.3	12.8	14	8.0	12.5	14.5	14	290	297.6	305	14	7.1	8.1	8.2	14
17 to 18	9.5	11.1	12.8	11	7.9	12.3	14.4	11	278	295.5	304	11	7.0	8.0	8.2	11
20 to 21	9.5	11.3	12.8	14	7.9	12.5	14.4	14	288	296.6	302	14	6.9	8.0	8.2	14
24 to 25	9.5	10.9	12.8	9	7.8	12.1	14.4	11	289	295.5	300	11	7.9	8.2	9.8	11
27 to 28	9.5	11.3	12.7	14	7.8	12.4	14.4	14	280	296.4	306	14	6.7	8.0	8.3	14

[1] Number of observations.

Appendix A

Sediment Core Data

Appendix A
Proposed Diffuser Site Sediment Core Data

Date	Location	Site	Pct. Gravel	Pct. Sand	Pct. Silt	Pct. Clay
Nov. 95	S3500	A-25D	0.00	85.76	9.75	4.49
Nov. 95	S3500	A-25E	0.10	78.55	19.11	2.24
Nov. 95	S3500	A-25F	0.05	80.93	14.21	4.81
Nov. 95	S3500	B+125A	0.00	81.71	13.64	4.65
Nov. 95	S3500	B+125B	0.00	69.84	26.48	3.68
Nov. 95	S3500	B+250A	0.30	78.76	16.30	4.64
Nov. 95	S3500	B+250C	0.45	83.33	13.66	2.56
Nov. 95	S3500	B+25A	0.05	82.40	13.54	4.01
Nov. 95	S3500	B+25B	0.00	81.90	15.86	2.24
Nov. 95	S3500	B+500A	0.00	75.35	20.64	4.01
Nov. 95	S3500	B+500B	0.00	77.43	18.40	4.17
Nov. 95	S3500	B+750D	0.10	75.53	21.65	2.72
Nov. 95	S3500	B+750E	0.00	76.51	21.89	1.60
Nov. 95	S3500	B+750F	5.36	79.71	13.17	1.76
Nov. 95	S3500	B+75B	0.00	84.31	13.13	2.56
Nov. 95	S3500	B+75C	0.00	80.36	16.76	2.88
Nov. 95	S3500	B-125A	0.60	67.18	27.73	4.49
Nov. 95	S3500	B-125B	0.00	78.79	18.01	3.20
Nov. 95	S3500	B-250A	0.00	77.94	18.86	3.20
Nov. 95	S3500	B-250B	0.30	85.34	12.44	1.92
Nov. 95	S3500	B-25A	0.85	67.86	26.47	4.81
Nov. 95	S3500	B-25B	0.25	81.57	15.14	3.04
Nov. 95	S3500	B-500A	0.60	70.15	25.08	4.17
Nov. 95	S3500	B-500B	0.20	79.37	17.55	2.88
Nov. 95	S3500	B-750A	0.00	79.89	15.94	4.17
Nov. 95	S3500	B-750B	0.00	77.17	18.34	4.49
Nov. 95	S3500	B-75A	0.00	70.18	26.30	3.52
Nov. 95	S3500	B-75B	0.10	82.51	14.83	2.56
Nov. 95	S3500	B0D	0.00	79.59	17.21	3.20
Nov. 95	S3500	B0E	0.40	74.65	20.14	4.81
Nov. 95	S3500	B0F	0.05	84.02	12.73	3.20
Nov. 95	S3500	C+25D	0.05	78.33	16.94	4.68
Nov. 95	S3500	C+25E	0.80	78.47	19.13	1.60
Nov. 95	S3500	C+25F	0.00	72.24	22.95	4.81
Jun-96	S3500	A0	11.36	73.26	12.01	3.37
Jun-96	S3500	B+125	0.00	77.66	20.23	2.11
Jun-96	S3500	B+250	0.98	68.69	28.35	1.98
Jun-96	S3500	B+500	0.00	85.22	13.77	1.01
Jun-96	S3500	B+75	0.00	79.47	17.89	2.64
Jun-96	S3500	B+750	0.00	80.91	18.18	0.91
Jun-96	S3500	B-125	0.45	80.28	18.37	0.90
Jun-96	S3500	B-250	0.00	80.41	18.60	0.99
Jun-96	S3500	B-500	0.30	81.57	15.34	2.79
Jun-96	S3500	B-75	0.10	78.86	18.87	2.17
Jun-96	S3500	B-750	0.00	81.30	17.50	1.20
Jun-96	S3500	B0	0.00	84.44	14.37	1.19
Jun-96	S3500	C0	0.00	75.86	22.29	1.85
Jun-96	S3500	D+125	0.00	82.73	16.32	0.95

Appendix A
Proposed Diffuser Site Sediment Core Data

Date	Location	Site	Pct. Gravel	Pct. Sand	Pct. Silt	Pct. Clay
Jun-96	S3500	D+250	0.05	74.63	23.45	1.87
Jun-96	S3500	D+500	0.00	71.11	27.20	1.69
Jun-96	S3500	D+75	0.00	84.55	13.45	2.00
Jun-96	S3500	D+750	0.00	77.89	21.26	0.85
Oct. 96	C3501	A0	0.00	56.87	42.23	0.90
Oct. 96	C3501	B+125	0.30	69.23	28.93	1.54
Oct. 96	C3501	B+250	0.00	69.42	25.87	4.71
Oct. 96	C3501	B+500	0.00	77.40	20.09	2.51
Oct. 96	C3501	B+75	0.10	77.73	20.65	1.52
Oct. 96	C3501	B+750	0.00	90.95	7.43	1.62
Oct. 96	C3501	B-125	0.00	61.06	38.16	0.78
Oct. 96	C3501	B-250	0.00	76.14	22.24	1.62
Oct. 96	C3501	B-500	0.00	77.13	21.21	1.66
Oct. 96	C3501	B-75	0.00	60.04	39.26	0.70
Oct. 96	C3501	B-750	0.00	78.88	19.47	1.65
Oct. 96	C3501	B0	0.00	69.09	29.64	4.27
Oct. 96	C3501	C0	0.00	70.62	27.43	1.95
Oct. 96	C3501	D+125	0.00	73.72	24.46	1.82
Oct. 96	C3501	D+250	0.00	69.58	29.27	1.15
Oct. 96	C3501	D+500	0.00	75.16	23.10	1.74
Oct. 96	C3501	D+75	0.00	61.87	37.02	1.11
Oct. 96	C3501	D+750	0.00	90.92	7.93	1.15
Oct. 96	S3500	A0	0.40	71.36	27.88	0.36
Oct. 96	S3500	B+125	0.00	68.51	30.83	0.66
Oct. 96	S3500	B+250	0.00	72.86	25.73	1.41
Oct. 96	S3500	B+500	0.25	71.58	26.17	2.00
Oct. 96	S3500	B+75	0.00	75.88	22.11	2.01
Oct. 96	S3500	B+750	0.50	74.45	23.42	1.63
Oct. 96	S3500	B-125	0.00	75.99	21.91	2.10
Oct. 96	S3500	B-250	0.00	75.04	23.62	1.34
Oct. 96	S3500	B-500	0.10	73.31	24.49	2.10
Oct. 96	S3500	B-75	0.00	77.07	20.61	2.32
Oct. 96	S3500	B-750	0.00	75.41	23.08	1.51
Oct. 96	S3500	B0	0.20	71.22	26.60	1.98
Oct. 96	S3500	C0	0.00	74.84	22.81	2.35
Oct. 96	S3500	D+125	0.00	75.41	22.60	1.99
Oct. 96	S3500	D+250	0.35	82.40	16.11	1.14
Oct. 96	S3500	D+500	0.00	79.57	17.78	2.65
Oct. 96	S3500	D+75	0.00	71.97	25.86	2.17
Oct. 96	S3500	D+750	0.00	72.77	25.16	2.07
Apr-97	C3501	A0	0.10	77.55	19.83	2.50
Apr-97	C3501	B+125	0.00	75.92	21.67	2.41
Apr-97	C3501	B+250	0.25	49.08	50.30	3.36
Apr-97	C3501	B+500	0.24	64.60	33.41	1.75
Apr-97	C3501	B+75	0.00	74.25	23.44	2.31
Apr-97	C3501	B+750	0.30	76.12	19.53	4.04
Apr-97	C3501	B-125	0.00	89.28	9.61	1.11
Apr-97	C3501	B-250	0.00	70.91	27.33	1.76
Apr-97	C3501	B-500	0.00	72.08	25.02	2.90
Apr-97	C3501	B-75	0.00	84.40	12.72	2.89

Appendix A
Proposed Diffuser Site Sediment Core Data

Date	Location	Site	Pct. Gravel	Pct. Sand	Pct. Silt	Pct. Clay
Apr-97	C3501	B-750	0.72	72.79	25.75	0.74
Apr-97	C3501	B0	0.00	78.63	18.78	2.59
Apr-97	C3501	C0	0.00	84.11	13.91	1.98
Apr-97	C3501	D+125	0.00	82.16	16.90	0.94
Apr-97	C3501	D+250	0.71	81.69	16.67	0.93
Apr-97	C3501	D+500	0.00	66.77	32.60	0.62
Apr-97	C3501	D+75	0.05	81.15	17.88	0.92
Apr-97	C3501	D+750	0.10	85.50	11.34	3.06
Apr-97	S3500	A0	0.10	84.60	13.30	2.00
Apr-97	S3500	B+125	0.35	78.09	20.71	0.85
Apr-97	S3500	B+250	0.20	78.49	20.45	0.85
Apr-97	S3500	B+500	0.10	74.78	22.78	2.34
Apr-97	S3500	B+75	0.00	72.90	25.62	1.48
Apr-97	S3500	B+750	0.00	71.52	26.34	2.14
Apr-97	S3500	B-125	0.00	77.15	20.36	2.49
Apr-97	S3500	B-250	0.00	83.37	13.72	2.91
Apr-97	S3500	B-500	0.05	72.11	26.39	1.45
Apr-97	S3500	B-75	0.20	74.11	21.85	3.85
Apr-97	S3500	B-750	0.00	69.75	28.21	2.04
Apr-97	S3500	B0	0.25	82.31	15.55	1.89
Apr-97	S3500	C0	0.05	69.64	27.60	2.71
Apr-97	S3500	D+125	0.20	76.68	20.65	2.46
Apr-97	S3500	D+250	0.55	72.90	24.32	2.26
Apr-97	S3500	D+500	0.00	84.01	13.03	2.96
Apr-97	S3500	D+75	0.00	70.89	27.71	1.40
Apr-97	S3500	D+750	0.00	77.98	19.47	2.55

	Pct. Gravel	Pct. Sand	Pct. Silt	Pct. Clay
Mean	0.25	76.29	21.19	2.32
s.d.	1.13	6.57	6.88	1.15
Min	0	49.08	7.43	0.36
Max	11.36	90.95	50.30	4.81
UCL	2.46	89.17	34.67	4.58
LCL	-1.97	63.41	7.71	0.07

Appendix B

Biological Data

Appendix B
Proposed Diffuser Site Benthos Data

	Number of Benthos Organisms per Cubic Decimeter (dm^3)									
Date	**Nov. 95**	**Nov. 95**	**Nov. 95**	**Nov. 95**	**Nov. 95**	**Nov. 95**	**Nov. 95**	**Jun-96**	**Jun-96**	**Jun-96**
Location	**S3500**	**S3500**	**S3500**	**S3500**	**S3500**	**S3500**	**S3500**	**S3500**	**S3500**	**S3500**
Site	**B+75**	**B-75**	**B+250**	**B-250**	**B+750**	**D+75**	**D+500**	**B0**	**B-75**	**B-125**
Chironomidae										
Chironomidae immature		8						4	10	
Chironomini										
Chironomus					3					
Chryptochironomus									5	
Phaenopsectra	4									
Polypedilum						5				
Orthocladiinae			15	4		20				
Corynoneura					3					
Diplocladius										
Nanocaldius										
Orthocladius										
Psectrocladius										
Stilocladius										
Zalutschia										
Diamesinae										
Oligochaeta										
Tubificid immature	32	24	30	32	42				15	30
Potomothrix										
Naididae										
Piquetiella										
Hirudinae										
Marvinmeyeria										
Gastropoda										
Psudosuccinea		4								
Amnicola pilsbryi		8		4			5	4		
Bulimnea										
Fossaria										
Marstonia										
Physella			5							
Pleurocera										
Radix										
Valvata		4	5							
Valvata bicarinata								4		
Pelycepoda										
Dreissena polymorpha		4			3					5
Pisidium	4	8	20	8	3		15		5	
Turbellaria										
Amphipoda										
Pontoporeia hoyi						5				
Total Density (no./dm^3)	**40**	**60**	**75**	**48**	**54**	**30**	**20**	**12**	**35**	**35**
Richness	**3**	**7**	**5**	**4**	**5**	**3**	**2**	**3**	**4**	**2**
Simpson's Diversity	**.65**	**.21**	**.27**	**.48**	**.61**	**.48**	**.61**	**.27**	**.29**	**.75**
Shannon-Weiner Diversity	**.63**	**1.71**	**1.40**	**.98**	**.84**	**.87**	**.56**	**1.10**	**1.23**	**.41**

Appendix B
Proposed Diffuser Site Benthos Data

	Number of Benthos Organisms per Cubic Decimeter (dm^3)									
Date	Jun-96	Jun-96	Jun-96	Jun-96	Jun-96	Jun-96	Jun-96	Jun-96	Jun-96	Jun-96
Location	S3500	S3500	S3500	S3500	S3500	S3500	S3500	S3500	S3500	S3500
Site	B-250	B-500	B-750	B+75	B+125	B+250	B+500	B+750	D+75	D+125
Chironomidae										
Chironomidae immature		4					4	12	5	
Chironomini										
Chironomus										
Chryptochironomus										
Phaenopsectra				4						
Polypedilum						7				
Orthocladiinae										
Corynoneura										
Diplocladius										
Nanocaldius										
Orthocladius										
Psectrocladius										
Stilocladius										
Zalutschia										
Diamesinae										
Oligochaeta										
Tubificid immature	6	28	19	47	23	7	32		30	53
Potomothrix										
Naididae										
Piquetiella										
Hirudinae										
Marvinmeyeria										
Gastropoda										
Psudosuccinea									11	
Amnicola pilsbryi				4					11	
Bulimnea										
Fossaria										
Marstonia										
Physella										
Pleurocera										
Radix										
Valvata									5	
Valvata bicarinata										
Pelycepoda										
Dreissena polymorpha					4	28				
Pisidium									261	
Turbellaria										
Amphipoda										
Pontoporeia hoyi										
Total Density (no./dm^3)	6	32	19	55	27	42	36	12	323	53
Richness	1	2	1	3	2	3	2	1	6	1
Simpson's Diversity	1	.77	1	.74	.74	.49	.80	1	.66	1
Shannon-Weiner Diversity	0	.38	0	.52	.42	.87	.35	0	.75	0

Appendix B
Proposed Diffuser Site Benthos Data

	Number of Benthos Organisms per Cubic Decimeter (dm^3)									
Date	**Jun-96**	**Jun-96**	**Jun-96**	**Jun-96**	**Jun-96**	**Oct-96**	**Oct-96**	**Oct-96**	**Oct-96**	**Oct-96**
Location	**S3500**	**S3500**	**S3500**	**S3500**	**S3500**	**S3500**	**S3500**	**S3500**	**S3500**	**S3500**
Site	**D+250**	**D+500**	**D+750**	**A0**	**C0**	**B+750a**	**B+750b**	**B+500a**	**B+500b**	**B+250a**
Chironomidae										
Chironomidae immature		3			4					
Chironomini								4		
Chironomus										
Chryptochironomus		3					4		4	
Phaenopsectra										
Polypedilum						4	8	8		
Orthocladiinae										
Corynoneura										
Diplocladius										
Nanocaldius								4		
Orthocladius										
Psectrocladius										
Stilocladius										
Zalutschia										
Diamesinae										
Oligochaeta						24	20	32	44	60
Tubificid immature	30	12	4							
Potomothrix										
Naididae										
Piquetiella										
Hirudinae										
Marvinmeyeria										
Gastropoda										
Psudosuccinea								16		
Amnicola pilsbryi		6	4					24		
Bulimnea										
Fossaria								4		
Marstonia										
Physella								4		
Pleurocera										
Radix										
Valvata					4		8	16		
Valvata bicarinata		6								
Pelycepoda										
Dreissena polymorpha					4	24	12			
Pisidium	6	3	4					12		
Turbellaria										
Amphipoda										
Pontoporeia hoyi										
Total Density (no./dm^3)	**36**	**33**	**12**	**0**	**12**	**52**	**52**	**124**	**48**	**60**
Richness	**2**	**6**	**3**	**0**	**3**	**3**	**5**	**10**	**2**	**1**
Simpson's Diversity	**.71**	**.20**	**.27**	**1**	**.27**	**.42**	**.24**	**.15**	**.84**	**1**
Shannon-Weiner Diversity	**.45**	**1.64**	**1.10**	**0**	**1.10**	**.91**	**1.48**	**2.04**	**.29**	**0**

Appendix B
Proposed Diffuser Site Benthos Data

	Number of Benthos Organisms per Cubic Decimeter (dm^3)									
Date	**Oct-96**	**Oct-96**	**Oct-96**	**Oct-96**	**Oct-96**	**Oct-96**	**Oct-96**	**Oct-96**	**Oct-96**	**Oct-96**
Location	**S3500**	**S3500**	**S3500**	**S3500**	**S3500**	**S3500**	**S3500**	**S3500**	**S3500**	**S3500**
Site	**B+250b**	**B+125a**	**B+125b**	**B+75a**	**B+75b**	**B0a**	**B0b**	**B-75a**	**B-75b**	**B-125a**
Chironomidae										
Chironomidae immature										
Chironomini					4					
Chironomus										
Chryptochironomus		3		3	4			3		
Phaenopsectra										
Polypedilum					4			3		
Orthocladiinae										
Corynoneura										
Diplocladius										
Nanocaldius								3		
Orthocladius										
Psectrocladius										
Stilocladius										
Zalutschia										
Diamesinae										
Oligochaeta	21	15	28	18	32	9	16	9	15	24
Tubificid immature										
Potomothrix										
Naididae										
Piquetiella										
Hirudinae										
Marvinmeyeria										
Gastropoda										
Psudosuccinea							4	6	3	
Amnicola pilsbryi									3	
Bulimnea										
Fossaria										
Marstonia										
Physella										
Pleurocera										
Radix										
Valvata		6					32			
Valvata bicarinata										
Pelycepoda										
Dreissena polymorpha								12	6	
Pisidium								9	6	
Turbellaria										
Amphipoda										
Pontoporeia hoyi										
Total Density (no./dm^3)	**21**	**24**	**28**	**21**	**44**	**9**	**52**	**45**	**33**	**24**
Richness	**1**	**3**	**1**	**2**	**4**	**1**	**3**	**7**	**5**	**1**
Simpson's Diversity	**1**	**.45**	**1**	**.62**	**.54**	**1**	**.47**	**.16**	**.26**	**1**
Shannon-Weiner Diversity	**0**	**.90**	**0**	**.54**	**.89**	**0**	**.86**	**1.81**	**1.41**	**0**

Appendix B
Proposed Diffuser Site Benthos Data

	Number of Benthos Organisms per Cubic Decimeter (dm^3)									
Date	Oct-96	Oct-96	Oct-96	Oct-96	Oct-96	Oct-96	Oct-96	Oct-96	Oct-96	Oct-96
Location	S3500	S3500	S3500	S3500	S3500	S3500	S3500	S3500	S3500	S3500
Site	B-125b	B-250a	B-250b	B-500a	B-500b	B-750a	B-750b	D+75a	D+75b	D+125a
Chironomidae										
Chironomidae immature										
Chironomini										
Chironomus										
Chryptochironomus				3	6	9	8	8	3	
Phaenopsectra										
Polypedilum	3					3	8		18	
Orthocladiinae						3	4			
Corynoneura										
Diplocladius				3						
Nanocaldius										
Orthocladius										
Psectrocladius										
Stilocladius										
Zalutschia										
Diamesinae										
Oligochaeta	12	20	40	15	60	27	44	24	39	36
Tubificid immature										
Potomothrix										
Naididae										
Piquetiella										
Hirudinae										
Marvinmeyeria										
Gastropoda										
Psudosuccinea						3			3	
Amnicola pilsbryi		8	8	3		12	8	8		4
Bulimnea										
Fossaria										
Marstonia										
Physella										
Pleurocera										
Radix										
Valvata	3	12	8	12		12	12	8		8
Valvata bicarinata										
Pelycepoda										
Dreissena polymorpha									3	
Pisidium		20		6	6	6	4	8	6	
Turbellaria										
Amphipoda										
Pontoporeia hoyi										
Total Density (no./dm^3)	18	60	56	42	72	75	88	56	72	48
Richness	3	4	3	6	3	8	7	5	6	3
Simpson's Diversity	.47	.27	.54	.23	70.00	.20	.29	.25	.40	.29
Shannon-Weiner Diversity	.87	1.32	.80	1.57	.57	1.80	1.55	1.48	1.28	.72

Appendix B
Proposed Diffuser Site Benthos Data

	Number of Benthos Organisms per Cubic Decimeter (dm^3)									
Date	**Oct-96**	**Oct-96**	**Oct-96**	**Oct-96**	**Oct-96**	**Oct-96**	**Oct-96**	**Oct-96**	**Oct-96**	**Oct-96**
Location	**S3500**	**S3500**	**S3500**	**S3500**	**S3500**	**S3500**	**S3500**	**S3500**	**S3500**	**S3500**
Site	**D+125b**	**D+250a**	**D+250b**	**D+500a**	**D+500b**	**D+750a**	**D+750b**	**A0a**	**A0b**	**C0a**
Chironomidae										
Chironomidae immature										
Chironomini										
Chironomus										
Chryptochironomus										3
Phaenopsectra										
Polypedilum			15				8		4	
Orthocladiinae										
Corynoneura										
Diplocladius										
Nanocaldius										
Orthocladius										
Psectrocladius										
Stilocladius										
Zalutschia										
Diamesinae										
Oligochaeta	8	16	5	3	15	24	32	21	12	21
Tubificid immature										
Potomothrix										
Naididae										
Piquetiella										
Hirudinae										
Marvinmeyeria										
Gastropoda										
Psudosuccinea										
Amnicola pilsbryi				3			4			
Bulimnea										
Fossaria										
Marstonia										
Physella										
Pleurocera										
Radix										
Valvata	4	8			5				4	
Valvata bicarinata										
Pelycepoda										
Dreissena polymorpha			5	3				3		
Pisidium	4	8	5	6	5			3		
Turbellaria										
Amphipoda										
Pontoporeia hoyi										
Total Density (no./dm^3)	**16**	**32**	**30**	**15**	**25**	**24**	**44**	**27**	**20**	**24**
Richness	**3**	**3**	**4**	**4**	**3**	**1**	**3**	**3**	**3**	**2**
Simpson's Diversity	**.44**	**.35**	**.31**	**.23**	**.42**	**1**	**.56**	**.62**	**.41**	**.77**
Shannon-Weiner Diversity	**.86**	**1.04**	**1.24**	**1.33**	**.95**	**0**	**.26**	**.68**	**.95**	**.38**

Appendix B
Proposed Diffuser Site Benthos Data

	Number of Benthos Organisms per Cubic Decimeter (dm^3)									
Date	Oct-96	Oct-96	Oct-96	Oct-96	Oct-96	Oct-96	Oct-96	Oct-96	Oct-96	Oct-96
Location	S3500	C3501	C3501	C3501	C3501	C3501	C3501	C3501	C3501	C3501
Site	C0b	B+750a	B+750b	B+500a	B+500b	B+250a	B+250b	B+125a	B+125b	B+75a
Chironomidae										
Chironomidae immature										
Chironomini										
Chironomus										
Chryptochironomus				4		3				
Phaenopsectra										
Polypedilum				12	4	3				
Orthocladiinae										
Corynoneura										
Diplocladius										
Nanocaldius										
Orthocladius										
Psectrocladius										
Stilocladius										
Zalutschia										
Diamesinae										
Oligochaeta	28			32	36	24	24	15	24	40
Tubificid immature										
Potomothrix										
Naididae										
Piquetiella										
Hirudinae										
Marvinmeyeria										
Gastropoda										
Psudosuccinea										
Amnicola pilsbryi								3		
Bulimnea										
Fossaria										
Marstonia										
Physella										
Pleurocera										
Radix										
Valvata	16			4				6		
Valvata bicarinata										
Pelycepoda										
Dreissena polymorpha										4
Pisidium	8									
Turbellaria										
Amphipoda										
Pontoporeia hoyi										
Total Density (no./dm^3)	**52**	**0**	**0**	**52**	**40**	**30**	**24**	**24**	**24**	**44**
Richness	**3**	**0**	**0**	**4**	**2**	**3**	**1**	**3**	**1**	**2**
Simpson's Diversity	**.40**	**1**	**1**	**.43**	**.82**	**.65**	**1**	**.45**	**1**	**.83**
Shannon-Weiner Diversity	**.98**	**0**	**0**	**1.03**	**.33**	**.64**	**0**	**.90**	**0**	**.30**

Appendix B
Proposed Diffuser Site Benthos Data

	Number of Benthos Organisms per Cubic Decimeter (dm^3)									
Date	**Oct-96**	**Oct-96**	**Oct-96**	**Oct-96**	**Oct-96**	**Oct-96**	**Oct-96**	**Oct-96**	**Oct-96**	**Oct-96**
Location	**C3501**	**C3501**	**C3501**	**C3501**	**C3501**	**C3501**	**C3501**	**C3501**	**C3501**	**C3501**
Site	**B+75b**	**B0a**	**B0b**	**B-75a**	**B-75b**	**B-125a**	**B-125b**	**B-250a**	**B-250b**	**B-500a**
Chironomidae										
Chironomidae immature										
Chironomini										
Chironomus										
Chryptochironomus	4									
Phaenopsectra										
Polypedilum		5				4			8	3
Orthocladiinae										
Corynoneura										
Diplocladius										
Nanocaldius										
Orthocladius										
Psectrocladius										
Stilocladius										
Zalutschia										
Diamesinae										
Oligochaeta	16	10	28	44	48	52	28	52	36	27
Tubificid immature										
Potomothrix										
Naididae										
Piquetiella										
Hirudinae										
Marvinmeyeria										
Gastropoda										
Psudosuccinea										
Amnicola pilsbryi		10	4							6
Bulimnea										
Fossaria										
Marstonia										
Physella										
Pleurocera										
Radix										
Valvata		5		4		4				
Valvata bicarinata										
Pelycepoda										
Dreissena polymorpha						8				
Pisidium								4		
Turbellaria										
Amphipoda										
Pontoporeia hoyi										
Total Density (no./dm^3)	**20**	**30**	**32**	**48**	**48**	**68**	**28**	**56**	**44**	**36**
Richness	**2**	**4**	**2**	**2**	**1**	**4**	**1**	**2**	**2**	**3**
Simpson's Diversity	**.66**	**.25**	**.77**	**.84**	**1**	**.60**	**1**	**.86**	**.70**	**.59**
Shannon-Weiner Diversity	**.50**	**1.33**	**.38**	**.29**	**0**	**.79**	**0**	**.26**	**.47**	**.72**

Appendix B
Proposed Diffuser Site Benthos Data

	Number of Benthos Organisms per Cubic Decimeter (dm^3)									
Date	**Oct-96**	**Oct-96**	**Oct-96**	**Oct-96**	**Oct-96**	**Oct-96**	**Oct-96**	**Oct-96**	**Oct-96**	**Oct-96**
Location	**C3501**	**C3501**	**C3501**	**C3501**	**C3501**	**C3501**	**C3501**	**C3501**	**C3501**	**C3501**
Site	**B-500b**	**B-750a**	**B-750b**	**D+75a**	**D+75b**	**D+125a**	**D+125b**	**D+250a**	**D+250b**	**D+500a**
Chironomidae										
Chironomidae immature										
Chironomini										
Chironomus										
Chryptochironomus				3	3					
Phaenopsectra										
Polypedilum		5	4				4		3	
Orthocladiinae										
Corynoneura										
Diplocladius										
Nanocaldius										
Orthocladius										
Psectrocladius										
Stilocladius										
Zalutschia										
Diamesinae										
Oligochaeta	24	20	28	36	18	28	16	20	12	21
Tubificid immature										
Potomothrix										
Naididae										
Piquetiella										
Hirudinae										
Marvinmeyeria										
Gastropoda										
Psudosuccinea			8				4			
Amnicola pilsbryi			4						9	
Bulimnea										
Fossaria										
Marstonia										
Physella										
Pleurocera									3	
Radix										
Valvata			8					10	12	9
Valvata bicarinata										
Pelycepoda										
Dreissena polymorpha			4							
Pisidium										3
Turbellaria										
Amphipoda										
Pontoporeia hoyi										
Total Density (no./dm^3)	**24**	**25**	**56**	**39**	**21**	**28**	**24**	**30**	**39**	**33**
Richness	**1**	**2**	**6**	**2**	**2**	**1**	**3**	**2**	**5**	**3**
Simpson's Diversity	**1**	**.67**	**.29**	**.85**	**.85**	**1**	**.49**	**.54**	**.23**	**.47**
Shannon-Weiner Diversity	**0**	**.50**	**1.47**	**.27**	**.27**	**0**	**.87**	**.64**	**1.46**	**.86**

Appendix B
Proposed Diffuser Site Benthos Data

	Number of Benthos Organisms per Cubic Decimeter (dm^3)									
Date	**Oct-96**	**Oct-96**	**Oct-96**	**Oct-96**	**Oct-96**	**Oct-96**	**Oct-96**	**Apr-97**	**Apr-97**	**Apr-97**
Location	**C3501**	**C3501**	**C3501**	**C3501**	**C3501**	**C3501**	**C3501**	**S3500**	**S3500**	**S3500**
Site	**D+500b**	**D+750a**	**D+750b**	**A0a**	**A0b**	**C0a**	**C0b**	**B+750a**	**B+750b**	**B+500a**
Chironomidae										
Chironomidae immature										
Chironomini										
Chironomus										
Chryptochironomus							4		6	3
Phaenopsectra										
Polypedilum	20	12		6				4	6	
Orthocladiinae										
Corynoneura										
Diplocladius										
Nanocaldius										
Orthocladius								4		
Psectrocladius										
Stilocladius										
Zalutschia										
Diamesinae										
Oligochaeta	28	44	24	42	12	9	12	20	24	3
Tubificid immature										
Potomothrix										
Naididae										
Piquetiella										
Hirudinae										
Marvinmeyeria										
Gastropoda										
Psudosuccinea								4	6	
Amnicola pilsbryi			4					4	6	
Bulimnea										
Fossaria										
Marstonia								4		
Physella										
Pleurocera										
Radix										
Valvata	4							32		
Valvata bicarinata										
Pelycepoda										
Dreissena polymorpha										
Pisidium							4			
Turbellaria										
Amphipoda										
Pontoporeia hoyi										
Total Density (no./dm^3)	**52**	**56**	**28**	**48**	**12**	**9**	**20**	**72**	**48**	**6**
Richness	**3**	**2**	**2**	**2**	**1**	**1**	**3**	**7**	**5**	**2**
Simpson's Diversity	**.43**	**.66**	**.75**	**.78**	**1**	**1**	**.41**	**.28**	**.30**	**.40**
Shannon-Weiner Diversity	**.90**	**.52**	**.41**	**.38**	**0**	**0**	**.95**	**1.52**	**1.39**	**.69**

Appendix B
Proposed Diffuser Site Benthos Data

	Number of Benthos Organisms per Cubic Decimeter (dm^3)									
Date	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**
Location	**S3500**	**S3500**	**S3500**	**S3500**	**S3500**	**S3500**	**S3500**	**S3500**	**S3500**	**S3500**
Site	**B+500b**	**B+250a**	**B+250b**	**B+125a**	**B+125b**	**B+75a**	**B+75b**	**B0a**	**B0b**	**B-75a**
Chironomidae										
Chironomidae immature										
Chironomini										
Chironomus										
Chryptochironomus							4			4
Phaenopsectra										
Polypedilum	3		8			8	4		5	16
Orthocladiinae										
Corynoneura										
Diplocladius										
Nanocaldius										
Orthocladius										
Psectrocladius										
Stilocladius										
Zalutschia										
Diamesinae									5	
Oligochaeta		12	12	8	8	8	16	30	5	8
Tubificid immature										
Potomothrix										
Naididae										
Piquetiella										
Hirudinae										
Marvinmeyeria										
Gastropoda										
Psudosuccinea			72	48	12					
Amnicola pilsbryi	3	12	8	40	4		8	5		
Bulimnea										
Fossaria										
Marstonia		8		8	8	4				
Physella				92						
Pleurocera										
Radix										
Valvata	3	24	80	24	4	8	32	15		4
Valvata bicarinata										
Pelycepoda										
Dreissena polymorpha			4							
Pisidium		12	48	80	40	4	4			
Turbellaria										
Amphipoda										
Pontoporeia hoyi										
Total Density (no./dm^3)	**9**	**68**	**232**	**300**	**76**	**32**	**68**	**50**	**15**	**32**
Richness	**3**	**5**	**7**	**7**	**6**	**5**	**6**	**3**	**3**	**4**
Simpson's Diversity	**.25**	**.22**	**.26**	**.21**	**.32**	**.19**	**.29**	**.49**	**.29**	**.32**
Shannon-Weiner Diversity	**1.10**	**1.54**	**1.51**	**1.67**	**1.41**	**1.56**	**1.45**	**.90**	**1.10**	**1.21**

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Proposed Diffuser Site Benthos Data

	Number of Benthos Organisms per Cubic Decimeter (dm^3)									
Date	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**
Location	**S3500**	**S3500**	**S3500**	**S3500**	**S3500**	**S3500**	**S3500**	**S3500**	**S3500**	**S3500**
Site	**B-75b**	**B-125a**	**B-125b**	**B-250a**	**B-250b**	**B-500a**	**B-500b**	**B-750a**	**B-750b**	**D+75a**
Chironomidae										
Chironomidae immature										
Chironomini								4		
Chironomus										
Chryptochironomus				5						
Phaenopsectra										
Polypedilum			9	10	4	10	5	4	3	10
Orthocladiinae										
Corynoneura										
Diplocladius										
Nanocaldius										
Orthocladius										
Psectrocladius										
Stilocladius										
Zalutschia										
Diamesinae										
Oligochaeta	16	12	24	15	8	25	10	12	6	5
Tubificid immature										
Potomothrix										
Naididae										
Piquetiella										
Hirudinae										
Marvinmeyeria										
Gastropoda										
Psudosuccinea								4	6	
Amnicola pilsbryi	36	4	6	5	4			4	6	
Bulimnea										
Fossaria										
Marstonia										
Physella	4									
Pleurocera										
Radix										
Valvata	20	16	6	5	4	10	5	12	27	
Valvata bicarinata										
Pelycepoda										
Dreissena polymorpha								4	3	
Pisidium									12	5
Turbellaria										
Amphipoda										
Pontoporeia hoyi										
Total Density (no./dm^3)	**76**	**32**	**45**	**40**	**20**	**45**	**20**	**44**	**63**	**20**
Richness	**4**	**3**	**4**	**5**	**4**	**3**	**3**	**7**	**7**	**3**
Simpson's Diversity	**.33**	**.39**	**.35**	**.23**	**.24**	**.39**	**.34**	**.17**	**.24**	**.34**
Shannon-Weiner Diversity	**1.19**	**.97**	**1.19**	**1.49**	**1.33**	**1.00**	**1.04**	**1.80**	**1.64**	**1.10**

Appendix B
Proposed Diffuser Site Benthos Data

	Number of Benthos Organisms per Cubic Decimeter (dm^3)									
Date	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**
Location	**S3500**	**S3500**	**S3500**	**S3500**	**S3500**	**S3500**	**S3500**	**S3500**	**S3500**	**S3500**
Site	D+75b	D+125a	D+125b	D+250a	D+250b	D+500a	D+500b	D+750a	D+750b	A0a
Chironomidae										
Chironomidae immature										
Chironomini										
Chironomus										
Chryptochironomus			5					5		
Phaenopsectra										
Polypedilum		8	5		5	5		25		
Orthocladiinae										
Corynoneura										
Diplocladius										
Nanocaldius										
Orthocladius										
Psectrocladius										
Stilocladius										
Zalutschia								5		
Diamesinae										
Oligochaeta		12	10	4	25	25	12	30		5
Tubificid immature										
Potomothrix										
Naididae										
Piquetiella										
Hirudinae										
Marvinmeyeria										
Gastropoda										
Psudosuccinea				4						35
Amnicola pilsbryi			5					10		
Bulimnea										5
Fossaria										
Marstonia		8		4					4	5
Physella		4								10
Pleurocera										
Radix										
Valvata	5	16	20	12	5			20		80
Valvata bicarinata										
Pelycepoda										
Dreissena polymorpha								5		
Pisidium		4	10					10	4	60
Turbellaria										
Amphipoda										
Pontoporeia hoyi										
Total Density (no./dm^3)	**5**	**52**	**55**	**24**	**35**	**30**	**12**	**110**	**8**	**200**
Richness	**1**	**6**	**6**	**4**	**3**	**2**	**1**	**8**	**2**	**7**
Simpson's Diversity	**1**	**.19**	**.21**	**.30**	**.54**	**.71**	**1**	**.17**	**.43**	**.28**
Shannon-Weiner Diversity	**0**	**1.67**	**1.64**	**1.24**	**.80**	**.45**	**0**	**1.86**	**.69**	**1.46**

Appendix B
Proposed Diffuser Site Benthos Data

	Number of Benthos Organisms per Cubic Decimeter (dm^3)									
Date	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**
Location	**S3500**	**S3500**	**S3500**	**C3501**	**C3501**	**C3501**	**C3501**	**C3501**	**C3501**	**C3501**
Site	**A0b**	**C0a**	**C0b**	**B+750a**	**B+750b**	**B+500a**	**B+500b**	**B+250a**	**B+250b**	**B+125a**
Chironomidae										
Chironomidae immature										
Chironomini										
Chironomus										
Chryptochironomus										
Phaenopsectra										
Polypedilum			8	4			12			20
Orthocladiinae									5	
Corynoneura										
Diplocladius										
Nanocaldius										
Orthocladius										
Psectrocladius										
Stilocladius										
Zalutschia										
Diamesinae										
Oligochaeta	32	10	4	12	4		24	5	5	36
Tubificid immature										
Potomothrix										
Naididae										
Piquetiella										
Hirudinae										
Marvinmeyeria										
Gastropoda										
Psudosuccinea	40			4				5		
Amnicola pilsbryi	4		20	8			12			
Bulimnea	8									
Fossaria										
Marstonia	8									
Physella	8							5		
Pleurocera										
Radix	4									
Valvata	80	15	4	32	4	3	16	10	10	8
Valvata bicarinata										
Pelycepoda										
Dreissena polymorpha						3	32			
Pisidium	160		8				8	5		
Turbellaria										
Amphipoda										
Pontoporeia hoyi										
Total Density (no./dm^3)	**344**	**25**	**44**	**60**	**8**	**6**	**104**	**30**	**20**	**64**
Richness	**9**	**2**	**5**	**5**	**2**	**2**	**6**	**5**	**3**	**3**
Simpson's Diversity	**.29**	**.50**	**.27**	**.34**	**.43**	**.40**	**.20**	**.20**	**.34**	**.42**
Shannon-Weiner Diversity	**1.53**	**.67**	**1.41**	**1.29**	**.69**	**.69**	**1.68**	**1.56**	**1.10**	**.95**

Appendix B
Proposed Diffuser Site Benthos Data

	Number of Benthos Organisms per Cubic Decimeter (dm^3)									
Date	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**
Location	**C3501**	**C3501**	**C3501**	**C3501**	**C3501**	**C3501**	**C3501**	**C3501**	**C3501**	**C3501**
Site	**B+125b**	**B+75a**	**B+75b**	**B0a**	**B0b**	**B-75a**	**B-75b**	**B-125a**	**B-125b**	**B-250a**
Chironomidae										
Chironomidae immature										
Chironomini										
Chironomus										
Chryptochironomus		4								8
Phaenopsectra										
Polypedilum	5	4		10						
Orthocladiinae										
Corynoneura										
Diplocladius										
Nanocaldius										
Orthocladius										
Psectrocladius										
Stilocladius										
Zalutschia										
Diamesinae										
Oligochaeta	10	16	35	20		5	10		14	8
Tubificid immature										
Potomothrix										
Naididae										
Piquetiella										
Hirudinae					5					
Marvinmeyeria										
Gastropoda										
Psudosuccinea										
Amnicola pilsbryi			5							
Bulimnea										
Fossaria										
Marstonia				5	20					
Physella										
Pleurocera										
Radix										
Valvata	5		5			15	5			4
Valvata bicarinata										
Pelycepoda										
Dreissena polymorpha				20			5	5		
Pisidium			10	5		5		10		8
Turbellaria										
Amphipoda										
Pontoporeia hoyi										
Total Density (no./dm^3)	**20**	**24**	**55**	**60**	**25**	**25**	**20**	**15**	**14**	**28**
Richness	**3**	**3**	**4**	**5**	**2**	**3**	**3**	**2**	**1**	**4**
Simpson's Diversity	**.34**	**.48**	**.39**	**.25**	**.67**	**.42**	**.34**	**.52**	**1**	**.24**
Shannon-Weiner Diversity	**1.04**	**.87**	**1.10**	**1.45**	**.50**	**.95**	**1.04**	**.64**	**0**	**1.35**

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Proposed Diffuser Site Benthos Data

	Number of Benthos Organisms per Cubic Decimeter (dm^3)									
Date	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**
Location	**C3501**	**C3501**	**C3501**	**C3501**	**C3501**	**C3501**	**C3501**	**C3501**	**C3501**	**C3501**
Site	**B-250b**	**B-500a**	**B-500b**	**B-750a**	**B-750b**	**D+75a**	**D+75b**	**D+125a**	**D+125b**	**D+250a**
Chironomidae										
Chironomidae immature										
Chironomini										
Chironomus										
Chryptochironomus	10						5	5		
Phaenopsectra										
Polypedilum	15	5		25	20	4	10	15		12
Orthocladiinae										
Corynoneura										
Diplocladius										
Nanocaldius										
Orthocladius										
Psectrocladius										
Stilocladius									5	
Zalutschia										
Diamesinae										4
Oligochaeta	5	5		5	20	12	15	10	5	8
Tubificid immature										
Potomothrix										
Naididae										
Piquetiella										
Hirudinae										
Marvinmeyeria						4				
Gastropoda										
Psudosuccinea				5	15			5		
Amnicola pilsbryi				10	10				10	4
Bulimnea										
Fossaria										
Marstonia			5							
Physella										
Pleurocera					5					
Radix										
Valvata	5	5	10	20	20			5		4
Valvata bicarinata										
Pelycepoda										
Dreissena polymorpha							5		5	
Pisidium				10	20				15	4
Turbellaria										
Amphipoda										
Pontoporeia hoyi										
Total Density (no./dm^3)	**35**	**15**	**15**	**75**	**110**	**20**	**35**	**40**	**40**	**36**
Richness	**4**	**3**	**2**	**6**	**7**	**3**	**4**	**5**	**5**	**6**
Simpson's Diversity	**.26**	**.29**	**.52**	**.22**	**.16**	**.41**	**.29**	**.23**	**.23**	**.19**
Shannon-Weiner Diversity	**1.28**	**1.10**	**.64**	**1.62**	**1.87**	**.95**	**1.28**	**1.49**	**1.49**	**1.67**

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Proposed Diffuser Site Benthos Data

	Number of Benthos Organisms per Cubic Decimeter (dm^3)								
Date	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**
Location	**C3501**	**C3501**	**C3501**	**C3501**	**C3501**	**C3501**	**C3501**	**C3501**	**C3501**
Site	**D+250b**	**D+500a**	**D+500b**	**D+750a**	**D+750b**	**A0a**	**A0b**	**C0a**	**C0b**
Chironomidae									
Chironomidae immature									
Chironomini									
Chironomus									
Chryptochironomus		5			5		5		
Phaenopsectra									
Polypedilum		15	12	6		4	5	5	10
Orthocladiinae									
Corynoneura									
Diplocladius									
Nanocaldius									
Orthocladius									
Psectrocladius									
Stilocladius							5		
Zalutschia									
Diamesinae									
Oligochaeta		15	3	6	5	4	10	10	35
Tubificid immature									
Potomothrix									
Naididae									
Piquetiella									
Hirudinae									
Marvinmeyeria									
Gastropoda									
Psudosuccinea	18								25
Amnicola pilsbryi	18				5				45
Bulimnea									
Fossaria									
Marstonia	6								10
Physella									5
Pleurocera									
Radix									
Valvata	60	5	9	24	15	4	5	10	50
Valvata bicarinata									
Pelycepoda									
Dreissena polymorpha									
Pisidium	18			6				10	100
Turbellaria									
Amphipoda									
Pontoporeia hoyi									
Total Density (no./dm^3)	**120**	**40**	**24**	**42**	**30**	**12**	**30**	**35**	**280**
Richness	**5**	**4**	**3**	**4**	**4**	**3**	**5**	**4**	**8**
Simpson's Diversity	**.31**	**.29**	**.38**	**.37**	**.31**	**.27**	**.20**	**.24**	**.21**
Shannon-Weiner Diversity	**1.35**	**1.26**	**.97**	**1.15**	**1.24**	**1.10**	**1.56**	**1.35**	**1.75**

Appendix B
Proposed Diffuser Site Zooplankton Data

	Number of Zooplankton per Cubic Meter (No./M^3)										
Date	**May-95**	**May-95**	**May-95**	**May-95**	**May-95**	**May-95**	**Jun-96**	**Jun-96**	**Jun-96**	**Oct-96**	**Oct-96**
Location	**C3501**	**C3501**	**C3501**	**S3500**	**S3500**	**S3500**	**S3500**	**S3500**	**S3500**	**C3501**	**C3501**
Rotifera	1726	2474	1540	588	629	400					
Ascormorpha ovalis											
Asplanchna priodonta											
Asplanchna herricki							1218	1654	1231		
Karatella cochlearis										6	
Karatella crassa											9
Karatella longispina											
Ploesoma truncatum											
Polyarthra										211	307
Crustacea											
Cladocera	66	112	145	63	218	248					
Bosmina longirostris							26		13	508	567
Daphnia											
Microcyclops varicans rubellus							77	173	231		
Copepoda	21	33	12	11	30	19					
Diacyclops bicuspidatus thomasi										483	697
Diaptomus							667	1808	1065	2693	3409
Mesocyclops edax										19	19
Copepodids	1115	1412	1099	696	1173	799	179		114		
Nauplii	487	772	578	422	540	666	2038	1058	526	539	957
Total Density (no./cu. M)	**3416**	**4803**	**3374**	**1780**	**2590**	**2131**	**4205**	**4693**	**3180**	**4459**	**5965**
Richness	**3**	**3**	**3**	**3**	**3**	**3**	**4**	**3**	**4**	**6**	**6**
Simpson's Diversity	**0.38**	**0.38**	**0.35**	**0.32**	**0.31**	**0.29**	**0.35**	**0.32**	**0.3**	**0.41**	**0.38**
Shannon-Weiner Diversity	**1.09**	**1.11**	**1.18**	**1.22**	**1.29**	**1.34**	**1.24**	**1.19**	**1.36**	**1.22**	**1.27**
Date	**Oct-96**	**Oct-96**	**Oct-96**	**Oct-96**	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**	**Apr-97**	
Location	**C3501**	**S3500**	**S3500**	**S3500**	**C3501**	**C3501**	**C3501**	**S3500**	**S3500**	**S3500**	
Rotifera											
Ascormorpha ovalis					26		33	44	48	37	
Asplanchna priodonta					70	73	16	18	88	19	
Asplanchna herricki											
Karatella cochlearis		9			9						
Karatella crassa	9							44			
Karatella longispina											
Ploesoma truncatum							8		16	19	
Polyarthra	437	297	223	266	9			9		28	
Crustacea											
Cladocera											
Bosmina longirostris	325	604	455	415	35	21	24	18	8		
Daphnia							8				
Microcyclops varicans rubellus											
Copepoda											
Diacyclops bicuspidatus thomasi	362	1161	994	994							
Diaptomus	2619	5006	3873	3873	150	42	49	88	120	65	
Mesocyclops edax		19	9								
Copepodids		56	93	93	18		8	9	32	19	
Nauplii	446	762	734	734	3507	2681	1502	4123	5235	2233	
Total Density (no./cu. M)	**4198**	**7914**	**6381**	**6375**	**3824**	**2817**	**1648**	**4353**	**5547**	**2420**	
Richness	**5**	**7**	**6**	**5**	**6**	**3**	**6**	**6**	**5**	**5**	
Simpson's Diversity	**0.42**	**0.44**	**0.41**	**0.41**	**0.84**	**0.9**	**0.83**	**0.89**	**0.89**	**0.85**	
Shannon-Weiner Diversity	**1.19**	**1.73**	**1.22**	**1.21**	**0.41**	**0.24**	**0.45**	**0.29**	**0.3**	**0.4**	

Appendix B
Proposed Diffuser Site Phytoplankton Data

Taxa	Number of Cells per milliliter (No./mL)							
Date	May-95	May-95	May-95	May-95	May-95	May-95	Jun-95	Jun-95
Location	C3501	C3501	C3501	S3500	S3500	S3500	S3500	S3500
Chlorophyta								
Actinastrum hantzschii Lagerheim								
Ankistrodesmus braunii (Naeg.) Brunthaller							5	7
Chlamydomonas globosa Snow	18	12	6	35	44	25		
Chlamydomonas sp. Ehrenberg					13	18	54	43
Chlorella/Chlorococcum humicola (Naeg.) Rabenhorst	30	23	7	16	18	45	60	84
Cosmarium sp. Corda							3	1
Elakatotrhix viridis (Snow) Printz								
Golenkinia paucispina West & West			0.5		1		19	12
Pediastrum boryanum (Turp.) Meneghini								
Pediastrum simplex (Meyen) Lemmermann								
Scenedesmus bijuga (Turp.) Lagerheim							1	
Scenedesmus brasiliensis Bohlin								
Scenedesmus quadricauda (Turp.) deBrebisson							4	
Scenedesmus sp. Meyen								
Selenastrum minutum (Naeg.) Collins							37	28
Selenastrum westii G.M. Smith								
Sphaerocystis schroeteri Chodat		35						
Unknown green spheres								
Cyanophyta								
Agmenellum tenuissima Lemmermann								
Aphanocapsa delicatissima West & West		35		10				
Chroococcus limneticus Lemmermann					4	1		
Chroococcus minor (Kuetz.) Naegeli	7			4	8		10	7
Gomphosphaeria lacustris			0.5	1		3		
Microcystis aeruginosa Kuetz. *amend* Elenkin							1	3
Microcystis incerta Lemmermann				8	11			
Oscillatoria liimnetica Vaucher		18					2	
Chrysophyta								
Cladomonas fruticulosa Stein	35			10			4	
Dinobryon cylindricum Imhoff ex. Ahlstrom							19	18
Dinobryon sociale var. americum (Brunn.) Bachmann	320	359	336	465	314	420	194	91
Mallomonas caudata Iwanoff	14	16	5	41	37	20	10	15
Mallomonas sp. Perty								
Pyrrhophyta								
Chroomonas nordstedtii Hansgirg.								
Glenodinium pulvisculus (Ehr.) Stein								1
Cryptophyta								
Cryptomonas erosa Ehrenberg	23	32	9	23	37	52		
Euglenophyta								
Euglena Ehrenberg	4	7	6	3	6	1		
Bacillariophyta (Diatoms)	440	523	265	455	518	654	253	210
Total Non-Diatom Algae Density (cells/mL)	**451**	**537**	**370**	**616**	**493**	**585**	**423**	**310**
Richness	**8**	**9**	**8**	**11**	**11**	**9**	**15**	**12**
Simpson's Diversity	**0.52**	**0.46**	**0.82**	**0.58**	**0.43**	**0.53**	**0.26**	**0.19**
Shannon-Weiner Diversity	**1.11**	**1.29**	**0.48**	**1.03**	**1.37**	**1.06**	**1.80**	**1.90**

Appendix B
Proposed Diffuser Site Phytoplankton Data

Taxa	Number of Cells per milliliter (No./mL)							
Date	Jun-95	Oct-96	Oct-96	Oct-96	Oct-96	Oct-96	Oct-96	Apr-97
Location	S3500	C3501	C3501	C3501	S3500	S3500	S3500	C3501
Chlorophyta								
Actinastrum hantzschii Lagerheim					2			
Ankistrodesmus braunii (Naeg.) Brunthaller	7			1				
Chlamydomonas globosa Snow								
Chlamydomonas sp. Ehrenberg	35	108	58	77	78	55	94	42
Chlorella/Chlorococcum humicola (Naeg.) Rabenhorst	32	31	20	36	48	47	61	42
Cosmarium sp. Corda			1					
Elakatotrhix viridis (Snow) Printz	2							
Golenkinia paucispina West & West	10							
Pediastrum boryanum (Turp.) Meneghini		2	1	2	4	3	2	
Pediastrum simplex (Meyen) Lemmermann		1	2	2			1	
Scenedesmus bijuga (Turp.) Lagerheim								
Scenedesmus brasiliensis Bohlin								
Scenedesmus quadricauda (Turp.) deBrebisson		4	1	1		4	2	
Scenedesmus sp. Meyen		3	7	6	1	1	3	
Selenastrum minutum (Naeg.) Collins	25							
Selenastrum westii G.M. Smith						2		
Sphaerocystis schroeteri Chodat								
Unknown green spheres								
Cyanophyta								
Agmenellum tenuissima Lemmermann						1	1	
Aphanocapsa delicatissima West & West								
Chroococcus limneticus Lemmermann								6
Chroococcus minor (Kuetz.) Naegeli	7							
Gomphosphaeria lacustris								
Microcystis aeruginosa Kuetz. *amend* Elenkin	2			1				
Microcystis incerta Lemmermann								
Oscillatoria liimnetica Vaucher								
Chrysophyta								
Cladomonas fruticulosa Stein	7	33	24	29	61	44	50	93
Dinobryon cylindricum Imhoff *ex.* Ahlstrom	35							
Dinobryon sociale var. americum (Brunn.) Bachmann	134		1					3
Mallomonas caudata Iwanoff	13							9
Mallomonas sp. Perty		19	8	15	16	9	22	
Pyrrhophyta								
Chroomonas nordstedtii Hansgirg.		200	116	195	124	105	203	75
Glenodinium pulvisculus (Ehr.) Stein								
Cryptophyta								
Cryptomonas erosa Ehrenberg								
Euglenophyta								
Euglena Ehrenberg								
Bacillariophyta (Diatoms)	359	437	284	452	289	335	410	185
Total Non-Diatom Algae Density (cells/mL)	**309**	**401**	**239**	**365**	**334**	**271**	**439**	**270**
Richness	**12**	**9**	**11**	**11**	**8**	**10**	**10**	**7**
Simpson's Diversity	**0.23**	**0.33**	**0.31**	**0.35**	**0.25**	**0.25**	**0.29**	**0.24**
Shannon-Weiner Diversity	**1.86**	**1.37**	**1.48**	**1.4**	**1.54**	**1.59**	**1.47**	**1.55**

Appendix B
Proposed Diffuser Site Phytoplankton Data

Taxa	Number of Cells per milliliter (No./mL)				
Date	Apr-97	Apr-97	Apr-97	Apr-97	Apr-97
Location	C3501	C3501	S3500	S3500	S3500
Chlorophyta					
Actinastrum hantzschii Lagerheim					
Ankistrodesmus braunii (Naeg.) Brunthaller		3		3	3
Chlamydomonas globosa Snow					
Chlamydomonas sp. Ehrenberg	48	36	33	36	54
Chlorella/Chlorococcum humicola (Naeg.) Rabenhorst	60	69	24	48	39
Cosmarium sp. Corda					
Elakatotrhix viridis (Snow) Printz					
Golenkinia paucispina West & West					
Pediastrum boryanum (Turp.) Meneghini					
Pediastrum simplex (Meyen) Lemmermann					
Scenedesmus bijuga (Turp.) Lagerheim					
Scenedesmus brasiliensis Bohlin					
Scenedesmus quadricauda (Turp.) deBrebisson	3	3		3	
Scenedesmus sp. Meyen					
Selenastrum minutum (Naeg.) Collins					
Selenastrum westii G.M. Smith	3	3			
Sphaerocystis schroeteri Chodat					
Unknown green spheres	3	6	12		6
Cyanophyta					
Agmenellum tenuissima Lemmermann		3		3	
Aphanocapsa delicatissima West & West					
Chroococcus limneticus Lemmermann	6	12	3	3	3
Chroococcus minor (Kuetz.) Naegeli					
Gomphosphaeria lacustris					
Microcystis aeruginosa Kuetz. *amend* Elenkin					
Microcystis incerta Lemmermann					
Oscillatoria liimnetica Vaucher					
Chrysophyta					
Cladomonas fruticulosa Stein	87	120	66	84	75
Dinobryon cylindricum Imhoff *ex.* Ahlstrom					
Dinobryon sociale var. americum (Brunn.) Bachmann			3		3
Mallomonas caudata Iwanoff	27	18	21	9	12
Mallomonas sp. Perty					
Pyrrhophyta					
Chroomonas nordstedtii Hansgirg.	87	60	48	36	57
Glenodinium pulvisculus (Ehr.) Stein					
Cryptophyta					
Cryptomonas erosa Ehrenberg					
Euglenophyta					
Euglena Ehrenberg					
Bacillariophyta (Diatoms)	162	110	56	89	121
Total Non-Diatom Algae Density (cells/mL)	**324**	**333**	**210**	**225**	**252**
Richness	**9**	**11**	**8**	**9**	**9**
Simpson's Diversity	**0.20**	**0.21**	**0.20**	**0.23**	**0.20**
Shannon-Weiner Diversity	**1.71**	**1.76**	**1.76**	**1.64**	**1.7**

Appendix B
Proposed Diffuser Site Phytoplankton Diatom Data

	May-95						Jun-96			Oct-96	
Taxa	C3501	C3501	C3501	S3500	S3500	S3500	S3500	S3500	S3500	C3501	C3501
Achnanthes affinis Grunow											
Achnanthes exigua Grun. in Cleve & Grunow								1	2		
Achnanthes exigua var. *heterovalvata* Krasske										2	1
Achnanthes clevei var. rostrata Hustedt						1					
Achnanthes flexella Kutzing									1		
Achnanthes lanceolata var. *rostrata* (Ostrup.) Hustedt											
Achnanthes linearis W. Smith											
Achnanthes microcephala Kutzing										1	
Achnanthes minutissima Kutzing		1			3	3	1	1	1	9	1
Amphipleura pellucida Kutzing											
Amphora pediculus Kutzing	1	1	1	2	3	3	1	1	1	1	1
Amphora perpusilla (Grun.) Grunow		2	1	1	3	1		1	1	1	1
Anomoeoneis serians var. *brachysira* (deBreb.) Husted										1	
Anomoeoneis vitrea (Grun.) Ross										6	1
Asterionella formosa Hassal	44	36	16	17	26	45	19	8	25	9	19
Aulacoseira ambigua (Grun.) Simonsen											
Aulacoseira distans var. *lirata*				3	7	9					
Aulacoseira granulata (Ehr.) Simonson							2	1	1		
Aulacoseira islandica (O. Muller) Simonsen						6					
Aulacoseira italica (Ehr.) Simonson											
Aulacoseira italica var. *tenuissima* (Grun.) Simonson								1	1	1	1
Caloneis bacillum (Grun.) Meresch.						1					
Cocconeis pediculus Ehrenberg											
Cocconies placentula var. *euglypta* (Ehr.) Cleve							1		2	4	4
Cocconeis placentula var. *lineata* Cleve	3	6	3	3	3	5					
Cocconeis thumensis A. Mayer				1	1	1					
Cyclotella compta (Ehr.) Kutzing										2	1
Cyclotella meneghiniana Kutzing											
Cyclotella michiginiana Skv.	5	3	1	6	9	8				10	8
Cyclotella ocellata Pant.							1	1	3	49	15
Cyclotella pseudostelligera Husted							1	1	1		
Cyclotella socialis Schutt										3	
Cyclotella stelligera (Cleve et Grun.) V.H.	3	3	1	3	3	1	3	1	4	11	11
Cymatopleura elliptica (deBreb.) W. Smith											
Cymatopleura solea (deBreb.) W. Smith					1						
Cymbella affinis Kutzing										6	
Cymbella amphicephala Naegeli											
Cymbella cuspidata Kutzing		1	1	1	3	1					
Cymbella microcephala Grunow										2	
Cymbella minuta var. *pseudogracilis* (Choln.) Reim						1					
Cymbella naviculiformis Auerswald											1
Cymbella parva (W. Smith) Cleve											
Cymbella perpusilla A. Cleve										7	
Cymbella prostata (Berkeley) Cleve										1	
Cymbella ventricosa Kutzing										1	
Diatoma anceps (Ehr.) Grunow		1									
Diatoma tenuis Agardh	44	71	46	68	72	90	35	25	40	4	1
Diatoma tenuis var. *elongatum* Lyngbye	78	90	39	54	55	79	92	70	98		
Diatoma vulgare Bory											
Diatoma vulgare var. Breve	1	6	2	5	5	6	1	1	3		
Diploneis ovalis (Hilse.) Cleve											
Diploneis puella (Schumann) Cleve						1					
Epithemia emarginata Andrews	1										
Fragilaria brevistriata Grunow										1	
Fragilaria capucina Desmzeires			1			4					
Fragilaria capucina var. *gracilis* (Oestr.) Hustedt	25	39	17	40	39	33					
Fragilaria capucina var. *mesolepta* (Rabh.) Grunow	26	36	11	18	19	33					

Appendix B
Proposed Diffuser Site Phytoplankton Diatom Data

	May-95						Jun-96			Oct-96	
Taxa	C3501	C3501	C3501	S3500	S3500	S3500	S3500	S3500	S3500	C3501	C3501
Fragilaria capucina var. *vaucheriae* (Kutz.) Lange-Bertalot	49	45	18	21	7	16		1			
Fragilaria consturens (Ehr.) Grunow											
Fragilaria construens var. *binodis* (Ehr.) Grunow	6	10	20	48	67	85					
Fragilaria construens var. *venter* (Ehr.) Grunow		3	5	32	28	37				4	1
Fragilaria crotonensis Kitton		6	4			15			9	4	8
Fragilaria delicatissima (W. Smith) Lange-Bertalot											
Fragilaria intermedia Grunow										1	2
Fragilaria pinnata Ehrenberg	1	2	2	9	5	6					
Fragilaria tenera (W. Smith) Lange-Bertalot											
Fragilaria virescens Ralfs							21	29	44	7	3
Gomphonema angustatum var. *producta* Grunow										3	
Gomphonema intricatum Kutzing											1
Gomphonema olivaceum (Lyngbye) Kutzing								1			
Gomphonema parvulum (Kutz.) Grunow											
Gyrosigma acuminatum (Kutz.) Rabh.			1								
Melosira varians C.A. Agardh	1	2	1	1	3	4					
Navicula 2	1	1									
Navicula arvensis Hust.			1	1	5	2					1
Navicula capitata Ehrenberg	1	7	2	4	6	3					
Navicula capitata var. *lunebergensis* (Grun.) Patrick											
Navicula cincta (Ehr.) Kutzing											
Navicula cohnii (Hilse.) Grunow										2	
Navicula contenta Grunow											
Navicula cryptocephala Kutzing	1	4	2	9	11	6	1		1	2	2
Navicula cryptocephala var. *exilis* Kutzing								1			
Navicula frugalis Hustedt											
Navicula gastrum (Ehr.) Donkin							1	1	1		
Navicula gracilis Ehrenberg											
Navicula hungarica Grunow								1	1	3	
Navicula lacustris Gregory	1	1			1	1					
Navicula menisculus Schumann										1	2
Navicula minima Grunow		1	1		1						1
Navicula mutica Kutzing											
Navicula nitrophila B. Petersen								1			
Navicula perpusilla Grunow											
Navicula pseudoreinhardtii Patrick	1	3	1	1	3	2					
Navicula pupula Kutzing				1	1		1				
Navicula pupula var. *mutata* (Krasske) Hustedt	1	1									
Navicula pusio Cleve	1	1	3	1	3	3					
Navicula radiosa Kutzing				1		1		1	1		1
Navicula radiosa var. *tenella* (deBreb. *ex* Katz.) Grunow					1	1					
Navicula schmassmannii Hustedt											
Navicula seminulum Grunow										2	1
Navicula 1										1	
Navicula subtilissima Cleve	1										
Navicula symmetrica Patrick		1	2		1	3					
Navicula variostrata Krasske											1
Neidium dubium (Ehr.) Cleve								1			
Nitzschia (longissima?) (deBreb.) Ralfs									11		
Nitzschia acicularis W. Smith	15	10	1	5	5	7	7	2	5	1	
Nitzschia amphibia Grunow				1							
Nitzschia angustata (W. Smith) Grunow	1	1	2	2	2	6					
Nitzschia denticula Grunow										1	
Nitzschia dissipata (Kutz.) Grunow	10	4	3	9	5	4					
Nitzschia fonticola Grunow	3	8	2	2	3	6					
Nitzschia frustulum Grunow		3		1			2	1	1	30	11
Nitzschia GLRD 1			1	4	1	4					

Appendix B
Proposed Diffuser Site Phytoplankton Diatom Data

	May-95						Jun-96			Oct-96	
Taxa	C3501	C3501	C3501	S3500	S3500	S3500	S3500	S3500	S3500	C3501	C3501
Nitzschia gracilis Hantzsch.	10	11	9	9	13	23			3		
Nitzschia linearis W. Smith				4	5	6		1	1	3	1
Nitzschia paleacea Grunow	6	5	1	5	3	4				64	48
Nitzschia romana Grunow										61	30
Nitzschia sublinearis Hustedt	13	13	5	5	17	15					
Nitzschia thermalis Kutzing			1								
Rhizosolenia eriensis H.L. Smith							1	1	3		
Rhoicosphenia curvata (Kutz.) Grunow	2	1	1	2	3	1					
Sellophora bacillum (Ehr.) D. Mann		1									
Stephanodiscus alpinus Hust.							2	3	5	25	17
Stephanodiscus hantzschii Grun. in Cleve & Grunow	46	45	17	30	40	29	20	18	22	43	47
Stephanodiscus hantzschii var. *tenuis* (Hust.) Hakansson & Stoermer							10	6	16	33	35
Stephanodiscus niagarae Ehrenberg										3	
Stephanodiscus parvus Stoermer & Hakansson	13	17	6	5	6	4	3	2	1		
Surirella didyma Kutzing		1	1	2	1	1					
Surirella linearis W. Smith										4	1
Surirella ovata Kutzing	1			1	1						
Surirella ovata var. *pinnata* W. Smith											1
Synedra acus var. *angustissima* Grunow							9	11	17	4	2
Synedra delicatissima W. Smith	13	8	7	11	10	11	10	9	23		
Synedra nana Meister							4	1			
Synedra pulchella Kutzing			1								
Synedra ulna (Nitz.) Ehrenberg	2	2	2	1	2	1				2	
Synedra ulna var. *chaseana* Thomas	11	6	4	5	9	10		1	2		
Synedra ulna var. *danica* (Kutz.) Grunow							5	4	5		
Tabellaria flocculosa (Roth) Kutzing		1			1	1					
Tabellaria quadriseptata Knudson	1	1	1	1	1	2		2		1	1
Total Diatom Density (cells/mL)	**440**	**523**	**265**	**455**	**518**	**654**	**253**	**210**	**359**	**437**	**284**
Richness	**38**	**47**	**45**	**46**	**50**	**54**	**26**	**36**	**35**	**47**	**37**
Simpson's Diversity	**0.08**	**0.08**	**0.08**	**0.07**	**0.07**	**0.07**	**0.17**	**0.15**	**0.13**	**0.08**	**0.09**
Shannon-Weiner Diversity	**2.78**	**2.93**	**3.01**	**3.03**	**3.12**	**3.12**	**2.29**	**2.46**	**2.51**	**2.95**	**2.69**

Appendix B
Proposed Diffuser Site Phytoplankton Diatom Data

	Oct-96				Apr-97					
Taxa	C3501	S3500	S3500	S3500	C3501	C3501	C3501	S3500	S3500	S3500
Achnanthes affinis Grunow										1
Achnanthes exigua Grun. in Cleve & Grunow										
Achnanthes exigua var. *heterovalvata* Krasske	3	3								
Achnanthes clevei var. rostrata Hustedt										
Achnanthes flexella Kutzing										
Achnanthes lanceolata var. *rostrata* (Ostrup.) Hustedt								1	1	
Achnanthes linearis W. Smith					1					1
Achnanthes microcephala Kutzing	1			2						
Achnanthes minutissima Kutzing	7	3	3	6	2	2		1	1	1
Amphipleura pellucida Kutzing										
Amphora pediculus Kutzing	1	3	2	3	1	1	2	1	1	1
Amphora perpusilla (Grun.) Grunow	1	3	2		1	2	1	1	1	1
Anomoeoneis serians var. *brachysira* (deBreb.) Husted			2							
Anomoeoneis vitrea (Grun.) Ross	2		7	4						
Asterionella formosa Hassal	3	10	5	8	1	2	1	1	1	1
Aulacoseira ambigua (Grun.) Simonsen					1	1			1	1
Aulacoseira distans var. *lirata*										
Aulacoseira granulata (Ehr.) Simonson										
Aulacoseira islandica var. *helvetica*										
Aulacoseira italica (Ehr.) Simonson										
Aulacoseira italica var. *tenuissima* (Grun.) Simonson			2	1						
Caloneis bacillum (Grun.) Meresch.				1						
Cocconeis pediculus Ehrenberg	3	1	1							
Cocconies placentula var. *euglypta* (Ehr.) Cleve	4	3	3	5	3	2	1	1	3	2
Cocconeis placentula var. *lineata* Cleve					1	1	1		1	1
Cocconeis thumensis A. Mayer						1	1	1	1	1
Cyclotella compta (Ehr.) Kutzing	2			2	1	1	1	1	1	1
Cyclotella meneghiniana Kutzing					1	1	1		1	1
Cyclotella michiginiana Skv.	12	11	9	11						
Cyclotella ocellata Pant.	44	14	42	45	10	3	1	1	1	2
Cyclotella pseudostelligera Husted										
Cyclotella socialis Schutt	2	3	1	4						
Cyclotella stelligera (Cleve et Grun.) V.H.	20	4	7	12	14	22	17	8	15	16
Cymatopleura elliptica (deBreb.) W. Smith					1	1		1		
Cymatopleura solea (deBreb.) W. Smith										
Cymbella affinis Kutzing	1		3							
Cymbella amphicephala Naegeli						1		1	1	1
Cymbella cuspidata Kutzing										
Cymbella microcephala Grunow	1		3		1	1	1	1		1
Cymbella minuta var. *pseudogracilis* (Choln.) Reim										
Cymbella naviculiformis Auerswald										
Cymbella parva (W. Smith) Cleve								1		
Cymbella perpusilla A. Cleve	1		4							
Cymbella prostata (Berkeley) Cleve	2									
Cymbella ventricosa Kutzing	3	4	2	1	1		1	1	1	1
Diatoma anceps (Ehr.) Grunow										
Diatoma tenuis Agardh	1	3	1	2	3	4	5	1	3	3
Diatoma tenuis var. *elongatum* Lyngbye										
Diatoma vulgare Bory					2	1	3	2	3	3
Diatoma vulgare var. Breve			1	1						
Diploneis ovalis (Hilse.) Cleve							1			
Diploneis puella (Schumann) Cleve										
Epithemia emarginata Andrews										
Fragilaria brevistriata Grunow				1						
Fragilaria capucina Desmzeires					5	1	3	1	2	2
Fragilaria capucina var. *gracilis* (Oestr.) Hustedt					1	1	1	1	1	1
Fragilaria capucina var. *mesolepta* (Rabh.) Grunow										

Appendix B
Proposed Diffuser Site Phytoplankton Diatom Data

Taxa		Oct-96				Apr-97					
		C3501	S3500	S3500	S3500	C3501	C3501	C3501	S3500	S3500	S3500
Fragilaria capucina var. *vaucheriae* (Kutz.) Lange-Bertalot						8	6	5	4	6	4
Fragilaria consturens (Ehr.) Grunow		1			1	4	5	1	1	3	3
Fragilaria construens var. *binodis* (Ehr.) Grunow											
Fragilaria construens var. *venter* (Ehr.) Grunow		1	3	3	9	1	3	2	1	1	1
Fragilaria crotonensis Kitton		3									
Fragilaria delicatissima (W. Smith) Lange-Bertalot						1	1	1	1		1
Fragilaria intermedia Grunow		3		6							
Fragilaria pinnata Ehrenberg						1	1	1	1	1	1
Fragilaria tenera (W. Smith) Lange-Bertalot							1				
Fragilaria virescens Ralfs		17	25	17	6						
Gomphonema angustatum var. *producta* Grunow		2		2	2						1
Gomphonema intricatum Kutzing											
Gomphonema olivaceum (Lyngbye) Kutzing											
Gomphonema parvulum (Kutz.) Grunow						1					
Gyrosigma acuminatum (Kutz.) Rabh.						1	1	1	1	1	1
Melosira varians C.A. Agardh							1		1	1	
Navicula 2											
Navicula arvensis Hust.						1			1	1	
Navicula capitata Ehrenberg						1	1	1	1	1	1
Navicula capitata var. *lunebergensis* (Grun.) Patrick						1	1	1	1	1	1
Navicula cincta (Ehr.) Kutzing									1	1	
Navicula cohnii (Hilse.) Grunow		1		2		1		1	1	1	1
Navicula contenta Grunow											
Navicula cryptocephala Kutzing		4		1		1	1	1	1	1	1
Navicula cryptocephala var. *exilis* Kutzing											
Navicula frugalis Hustedt										1	
Navicula gastrum (Ehr.) Donkin						1	1	1		1	0
Navicula gracilis Ehrenberg						1	1	1	1	1	1
Navicula hungarica Grunow		3		1	1						
Navicula lacustris Gregory							1	1		1	1
Navicula menisculus Schumann		1	2	2	3	3	2	1	1	1	1
Navicula minima Grunow		1				0	1	1	1	1	1
Navicula mutica Kutzing							0				
Navicula nitrophila B. Petersen											
Navicula perpusilla Grunow											
Navicula pseudoreinhardtii Patrick											
Navicula pupula Kutzing											
Navicula pupula var. *mutata* (Krasske) Hustedt											
Navicula pusio Cleve											
Navicula radiosa Kutzing		2	2								
Navicula radiosa var. *tenella* (deBreb. *ex* Katz.) Grunow						1		1	1	1	1
Navicula schmassmannii Hustedt				1							
Navicula seminulum Grunow					3	1		1	1		1
Navicula 1			3		1						
Navicula subtilissima Cleve									1		
Navicula symmetrica Patrick											
Navicula variostrata Krasske						1	1	1	1	1	3
Neidium dubium (Ehr.) Cleve									1		1
Nitzschia (longissima?) (deBreb.) Ralfs											
Nitzschia acicularis W. Smith					1	3	4	2	1	1	1
Nitzschia amphibia Grunow							1	1	1	1	
NItzschia angustata (W. Smith) Grunow											
Nitzschia denticula Grunow											
Nitzschia dissipata (Kutz.) Grunow					1	2	1	1	1	1	
Nitzschia fonticola Grunow											
Nitzschia frustulum Grunow		31	35	21	24	1	1	1			1
Nitzschia GLRD 1											

Appendix B
Proposed Diffuser Site Phytoplankton Diatom Data

	Oct-96				Apr-97					
Taxa	C3501	S3500	S3500	S3500	C3501	C3501	C3501	S3500	S3500	S3500
Nitzschia gracilis Hantzsch.										
Nitzschia linearis W. Smith	3	1		1		1	1	1	2	1
Nitzschia paleacea Grunow	64	47	51	64	19	19	7	4	4	11
Nitzschia romana Grunow	33	6	21	42	9	11	2	1	1	3
Nitzschia sublinearis Hustedt										
Nitzschia thermalis Kutzing										
Rhizosolenia eriensis H.L. Smith										
Rhoicosphenia curvata (Kutz.) Grunow		3			1	1	1	1	1	1
Sellophora bacillum (Ehr.) D. Mann					1	1		1	1	
Stephanodiscus alpinus Hust.	22	25	24	41	8	7	6	2	4	5
Stephanodiscus hantzschii Grun. in Cleve & Grunow	76	37	48	50	44	35	29	12	21	26
Stephanodiscus hantzschii var. *tenuis* (Hust.) Hakansson & Stoermer	55	24	29	38	23	14	9	6	8	12
Stephanodiscus niagarae Ehrenberg	1	2	2	3						
Stephanodiscus parvus Stoermer & Hakansson										
Surirella didyma Kutzing										
Surirella linearis W. Smith	2			3						
Surirella ovata Kutzing										
Surirella ovata var. *pinnata* W. Smith	1	2		6	1	1	1	1		1
Synedra acus var. *angustissima* Grunow	6	3	4	1	3	1	2	1	1	3
Synedra delicatissima W. Smith										
Synedra nana Meister										
Synedra pulchella Kutzing										
Synedra ulna (Nitz.) Ehrenberg	1				1	1	1	1	1	1
Synedra ulna var. *chaseana* Thomas										
Synedra ulna var. *danica* (Kutz.) Grunow										
Tabellaria flocculosa (Roth) Kutzing										
Tabellaria quadriseptata Knudson	2	4			1	1		1	1	1
Total Diatom Density (cells/mL)	**450**	**289**	**335**	**410**	**185**	**176**	**124**	**82**	**111**	**132**
Richness	**45**	**30**	**36**	**38**	**52**	**53**	**49**	**55**	**53**	**54**
Simpsons Diversity	**0.09**	**0.11**	**0.08**	**0.09**	**0.10**	**0.09**	**0.11**	**0.10**	**0.10**	**0.09**
Shannon-Weiner Diversity	**2.81**	**2.52**	**2.83**	**2.78**	**2.88**	**2.92**	**2.83**	**2.99**	**2.96**	**3.00**

Appendix C

Chemical Data

Appendix C
Lake Michigan Water Chemistry Data

Parameter	Units	May-95		Jun-96		Oct-96		Apr-97	
		C3501	S3500	S3500	S3500	C3501	S3500	C3501	S3500
pH	s.u.			7.0	6.9	8.1	8.1	8.5	8.3
Total Suspended Solids (TSS)	mg/L	2.0	3.0	0.9	0.9	2.5	2.0	0.9	0.9
Total Dissolved Solids (TDS)	mg/L	188	198	194	188	148	140	160	160
Alkalinity as $CaCO_3$	mg/L	110	110						
Chloride	mg/L	14.0	14.0	12.7	13.2	12.5	14.0	17.0	17.0
Total Organic Carbon (TOC)[1]	mg/L	3.20	3.20	4.30	4.50	2.50	2.60	14.00	20.00
Hardness as $CaCO_3$	mg/L	158	133	147	150	155	150	150	160
Total Kjeldahl Nitrogen (TKN)	mg/L	1.1	1.9			0.4	0.4	0.4	0.4
Nitrate/Nitrite	mg/L	1.50	0.29	0.35	0.34	0.30	0.40	0.34	0.09
Total Nitrogen	mg/L			1.74	1.56				
Total Phosphorus	mg/L	0.100	0.120	0.009	0.009	0.020	0.020	0.200	0.200
Ortho-Phosphorus	mg/L	0.009	0.050	0.009	0.009	0.020	0.020	0.200	0.200
Silica	mg/L	0.50	0.60	0.70	0.65	0.50	0.38	0.60	0.59
Sulfate	mg/L	25	26						
Total Calcium	mg/L	85	54						
Total Magnesium	mg/L	12	12						
Total Sodium	mg/L	7.7	7.0						
Total Potassium	mg/L	0.3	3.3						

[1]Method 9060 with extraction.

[2]Method 9060 total combustion.

Appendix C
Lake Michigan Water Chemistry Sampling Schedule

Parameter	Units	Method	Dates Collected [1]			
pH	s.u.	9040A		Jun-96	Oct-96	Apr-97
Total Suspended Solids (TSS)	mg/L	EPA160.2	May-95	Jun-96	Oct-96	Apr-97
Total Dissolved Solids (TDS)	mg/L	EPA160.1	May-95	Jun-96	Oct-96	Apr-97
Alkalinity as $CaCO_3$	mg/L	EPA310.2	May-95			
Chloride	mg/L	2951	May-95	Jun-96	Oct-96	Apr-97
Total Organic Carbon (TOC)	mg/L	EPA415.1	May-95	Jun-96	Oct-96	Apr-97
Hardness as $CaCO_3$	mg/L	EPA130.2	May-95	Jun-96	Oct-96	Apr-97
Total Kjeldahl Nitrogen (TKN)	mg/L	EPA351.1	May-95		Oct-96	Apr-97
Nitrate/Nitrite	mg/L	9200	May-95	Jun-96	Oct-96	Apr-97
Total Nitrogen	mg/L	Calc.		Jun-96		
Total Phosphorus	mg/L	EPA365.4	May-95	Jun-96	Oct-96	Apr-97
Ortho-Phosphorus	mg/L	EPA365.2	May-95	Jun-96	Oct-96	Apr-97
Silica	mg/L	6010	May-95	Jun-96	Oct-96	Apr-97
Sulfate	mg/L	EPA375.4	May-95			
Total Calcium	mg/L	EPA215.1	May-95			
Total Magnesium	mg/L	EPA242.1	May-95			
Total Sodium	mg/L	EPA273.1	May-95			
Total Potassium	mg/L	EPA258.1	May-95			

[1]Collection dates were May 23-25, 1995; June 5-6, 1996; October 21-24, 1996; and April 28-30, 1997.

Appendix C
In-Situ Water Quality Deteminations

Dissolved Oxygen (mg/L)														
Date	5/23/95	5/24/95	5/25/95	5/23/95	5/24/95	5/25/95	6/5/96	10/21/96	10/24/96	10/21/96	10/22/96	4/28/97	4/28/97	4/29/97
Location	C3501	C3501	C3501	S3500	S3500	S3500	S3500	C3501	C3501	S3500	S3500	C3501	S3500	S3500
Depth (ft)														
surface	11.0	12.5	12.0	10.9	12.6	12	10.3	9.6	9.9	9.6	9.7	11.6	11.3	12.7
2 to 3			12.0	10.9		12	10.3	9.6	9.8	9.6	9.7	11.5	11.3	12.7
5 to 6	11.1	12.6	12.0	11	12.6	12	10.3	9.6	9.8	9.6	9.6	11.6	11.2	12.6
8 to 9			12.0	11.1		12	10.3	9.6	9.8	9.6	9.6	12.1	11.7	12.6
11 to 12	11.1	12.6	12.0	11.1	12.6	12	10.4	9.6	9.8	9.5	9.5	12.1	11.7	13.3
14 to 15	11.2	12.6	12.0	11.1	12.6	12	10.4	9.7	9.8	9.5	9.7	12.2	12.1	12.8
17 to 18			12.0	11.1		12	10.6	9.7	9.8	9.5	9.7	12.2	12.2	12.8
20 to 21	11.1	12.6	12.0	11.1	12.6	12	10.6	9.7	9.9	9.5	9.7	12.2	12.2	12.8
24 to 25				11.4			10.6	9.6	9.8	9.5	9.7	12.2	12.2	12.8
27 to 28	11.5	12.6	12.0	11.5	12.6	12	10.6	9.7	9.8	9.5	9.7	12.2	12.3	12.7

Temperature (°C)														
Date	5/23/95	5/24/95	5/25/95	5/23/95	5/24/95	5/25/95	6/5/96	10/21/96	10/24/96	10/21/96	10/22/96	4/28/97	4/28/97	4/29/97
Location	C3501	C3501	C3501	S3500	S3500	S3500	S3500	C3501	C3501	S3500	S3500	C3501	S3500	S3500
Depth (ft)														
surface	13.3	13.3	13.7	14	13.3	13.5	15	14.8	13.6	14.7	15.1	9.7	10.7	8.5
2 to 3			13.7	14			15	14.8	13.6	14.7	15.1	9.7	10.7	8.5
5 to 6	13.3	13.3	13.7	13.3	13.3	13.5	15	14.8	13.6	14.7	15	9.1	10.7	8.5
8 to 9			13.7	13.2		13.5	14	14.6	13.6	14.7	14.7	8.4	8.9	8.5
11 to 12	13.3	13.3	13.7	13	13.3	13.5	14	14.5	13.6	14.4	14.5	8.2	8.4	8.4
14 to 15	13.3	13.3	13.7	13	13.3	13.5	14	14.5	13.6	14.4	14.3	8	8.2	8.4
17 to 18			13.7	13		13.5	14	14.4	13.6	14.4	14.2	7.9	8.1	8.3
20 to 21	13.3	13.3	13.7	12.7	13.3	13.5	14	14.4	13.6	14.4	14.2	7.9	8	8.3
24 to 25			13.7	12.5		13.5	13	14.4	13.6	14.3	14.2	7.8	7.9	8.3
27 to 28	13.3	13.3	13.7	12.2	13.3	13.5	13	14.4	13.6	14.4	14.2	7.9	7.8	8.3

Appendix C
In-Situ Water Quality Deteminations

Conductivity (µmhos/cm)														
Date	5/23/95	5/24/95	5/25/95	5/23/95	5/24/95	5/25/95	6/5/96	10/21/96	10/24/96	10/21/96	10/22/96	4/28/97	4/28/97	4/29/97
Location	C3501	C3501	C3501	S3500	S3500	S3500	S3500	C3501	C3501	S3500	S3500	C3501	S3500	S3500
Depth (ft)														
surface	301	295	298	301	291	289	300	308	294	306	299	313	318	291
2 to 3			290	299			301	308	294	309	298	313	317	286
5 to 6	296	292	290	296	298	289	304	308	291	305	298	311	315	287
8 to 9			291	296		290	297	306	294	305	297	303	306	291
11 to 12	289	289	292	295	301	290	305	305	298	301	294	303	303	290
14 to 15	305	293	291	296	300	292	300	305	294	304	292	301	304	290
17 to 18			294	297		289	300	304	294	301	289	301	303	278
20 to 21	300	301	293	296	297	296	300	300	288	302	289	300	300	290
24 to 25			293	294		294	300	300	289	300	289	300	298	294
27 to 28	306	301	292	294	297	280	302	300	294	300	289	300	298	297

pH (s.u.)														
Date	5/23/95	5/24/95	5/25/95	5/23/95	5/24/95	5/25/95	6/5/96	10/21/96	10/24/96	10/21/96	10/22/96	4/28/97	4/28/97	4/29/97
Location	C3501	C3501	C3501	S3500	S3500	S3500	S3500	C3501	C3501	S3500	S3500	C3501	S3500	S3500
Depth (ft)														
surface	8.2	8.2	8.2	8.2	8.2	8.2	8.1	8.1	8.2	8.2	8.2	7.9	7.9	7.4
2 to 3			8.2	8.2			8.1	8.1	8.2	8.2	8.2	7.9	7.9	7.4
5 to 6	8.2	8.2	8.2	8.2	8.2	8.1	8.1	8.1	8.2	8.2	8.2	7.9	7.9	7.3
8 to 9			8.2	8.2		8.1	8.1	8.1	8.2	8.2	8.2	7.9	8	7.3
11 to 12	8.2	8.2	8.2	8.2	8.2	8.1	8.1	8.1	8.2	8.2	8.2	7.9	8	7.2
14 to 15	8.2	8.2	8.2	8.2	8.1	8.1	8.1	8.1	8.2	8.2	8.1	7.9	8	7.1
17 to 18			8.2	8.2		8.1	8.1	8	8.2	8.2	8.1	7.9	8	7
20 to 21	8.2	8.2	8.2	8.2	8.1	8.1	8.1	8	8.2	8.2	8.1	7.9	8	6.9
24 to 25			8.2	8.2		8.1	8.1	8	8.1	8.2	8.1	7.9	8	9.8
27 to 28	8.2	8.1	8.1	8.2	8.1	8.1	8.1	8	8.1	8.3	8.1	7.9	8	6.7

7

ATTACHMENT 7

STORET SYSTEM RETRIEVAL FOR
WHITING INTAKE

STORET SYSTEM RETRIEVAL FOR WHITING INTAKE
1993 - 1996

DATE	TOT HARD CACO3 MG/L	CHROMIUM Cr, Tot UG/L	CHROMIUM Cr(VI)Total UG/L	CYANIDE Total MG/L	MANGANESE UG/L	NICKEL NI,TOT UG/L
1/12/93	142	k 4	k 10	k 0.005	95	k 4
2/23/93	148	k 4	k 10	k 0.005	8	k 4
3/16/93	148	k 4	k 10	k 0.005	16	k 4
5/11/93	148	k 4	k 10	k 0.005	k 6	k 4
8/2/93	146	k 4	k 10	k 0.005	k 6	k 6
9/8/93	137	k 4	k 10	0.009	k 6	k 8
10/27/93	137	k 4	k 10	k 0.005	k 6	k 8
11/17/93	155	k 4	k 10	k 0.005	k 6	k 8
2/2/94	166	k 4	k 10	k 0.005	k 6	k 6
3/2/94	154	k 4	k 10	k 0.005	k 6	k 6
3/15/94	152	k 4	k 10	k 0.005	k 6	k 6
4/26/94	148	k 4	k 10	k 0.005	k 6	k 6
6/1/94	134	k 4	k 10		k 6	k 6
8/1/94	142	k 4	k 10	0.006	k 6	k 6
8/31/94	138	k 4	k 10	k 0.005	k 6	k 6
10/3/94	154	k 4	k 10	k 0.005	8	k 6
11/9/94	151	k 4	k 10	k 0.005	72	k 6
1/18/95	139	k 4	k 10	k 0.005	k 6	k 6
3/7/95	161	k 4		k 0.005	8	k 6
4/26/95	145	k 4		k 0.005	6	k 6
5/18/95	143	k 4	k 10	k 0.005	k 6	k 6
6/15/95	134	k 4	k 10	k 0.005	k 6	k 6
7/26/95	138	k 4	k 10	k 0.005	k 6	k 6
8/29/95	132	k 4	k 10	k 0.005	k 6	k 6
9/26/95	136	k 4	k 10	k 0.005	k 6	k 6
10/24/95	148	k 4		k 0.005	k 6	k 6
11/14/95	140	k 4	k 10	k 0.005	14	k 6
12/20/95	146	k 4	k 10	k 0.005	8	k 6
1/22/96	160	k 3	k 10	k 0.005	10	k 6
2/27/96	150	4.6	k 10	k 0.005	6.8	k 6
3/25/96	158	4.3	k 10	k 0.005	13	k 6
4/23/96	152	k 6		k 0.005	17	k 6
5/21/96	164	k 3	k 10	k 0.005	8	k 6
6/18/96	162		k 10	k 0.005		
7/16/96	168	k 3	k 10	k 0.005	3.7	k 6
8/20/96	120	k 3	k 10	k 0.005	k 3	k 6
9/17/96	136	12	k 10	k 0.005	14	k 6
10/22/96	142	5.4	k 10	k 0.005	3.5	k 6
11/12/96	138	k 5	k 10	k 0.005	4.8	k 6
12/10/96	150	k 5	k 10	k 0.005	8.3	k 6
Count(93-96)	40	39	36	39	39	39
ND(93-96)	0	35	36	37	20	39
Average	146.55	4.26	10	0.0051	11.31	5.95
Minimum	120	3	10	0.005	3	4
Maximum	168	12	10	0.009	95	8
Stand Dev	10.4	1.4	0.0	0.00066	17.5	0.9
CV	0.07	0.33	0	0.128	1.55	0.14
Geomean (93-96)	146.2	0.54	0	0.0003	5.39	0

STORET SYSTEM RETRIEVAL FOR WHITING INTAKE
1993 - 1996

DATE	SELENIUM SE,TOT UG/L	COPPER CU,TOT UG/L	SULFATE SO4-TOT MG/L	ARSENIC AS,TOT UG/L	BARIUM BA,TOT UG/L	BERYLLIUM BE, TOT UG/L	IRON FE,TOT UG/L
1/12/93	1	13	30	1	23	k 1.2	1500
2/23/93	1	17	27	0.9	21		320
3/16/93	1	44	27	1	22		480
5/11/93	1	34	24	0.8	21		51
8/2/93	1	21	24	0.8	19	k 1.2	25
9/8/93	1	28	25	0.7	20		k 20
10/27/93	1	19	25	1.1	22		33
11/17/93	1	14	28	1	23		70
2/2/94	1	11	30	0.8	21		27
3/2/94	1	11	26	0.7	22		89
3/15/94	1	14	28	0.8	21		100
4/26/94	1	26	27	0.8	20		56
6/1/94	1	20	26	0.7	21		210
8/1/94	1	13		0.9	20		85
8/31/94	1	43	25	1	18		k 20
10/3/94	1	32	27	0.8	19		200
11/9/94	1	23		2	28		1900
1/18/95	1	22	24	0.8	17		150
3/7/95	1	20	28	1.1	21		300
4/26/95	1	22	25	0.6	20		180
5/18/95	1	17	26	0.9	21		81
6/15/95	1	14	22	0.6	20		24
7/26/95	1	17	24	0.9	20		k 20.
8/29/95	1	21	22	0.8	17		k 20
9/26/95	1	44	23	1.1	20		54
10/24/95	1	36	25	0.9	20		240
11/14/95	1	7	27	1.1	18		650
12/20/95	1	7	26	0.8	20		240
1/22/96	1	4.8	30	0.9	21		120
2/27/96	1	5.3	26	0.9	24		260
3/25/96	2	5.3	27	1.5	24		760
4/23/96	2	70	26	2	23		660
5/21/96	2	100	26	k 2	21		180
6/18/96			22				
7/16/96	2	55	23	k 2	20		58
8/20/96	2	40	22	k 2	20		24
9/17/96	2	36	23	2	24		310
10/22/96	2	31	26	k 2	20		51
11/12/96	2	25	27	k 2	19		77
12/10/96	2	41	30	k 2	21		130
Count(93-96)	39	39	38	39	39	2	39
ND(93-96)	38	0	0	6	0	2	4
Average	1.23	26.24	25.76	1.15	20.82	1.2	251
Minimum	1	5	22	1	17	1.2	20.0
Maximum	2	100	30	2	28	1.2	1,900
Stand Dev	0.4	18.9	2.3	0.50	2.1	0	391
CV	0.35	0.72	0.09	0.44	0.10	0	2
Geomean (93-96)	0.033	20.9	25.6646	1.03	20.7	0	113

STORET SYSTEM RETRIEVAL FOR WHITING INTAKE
1993 - 1996

DATE	IRON FE,DISS UG/L	LEAD PB,TOT UG/L	ZINC ZN,TOT UG/L	AMMONIA NH3+NH4- MG/L	CHLORIDE CL, MG/L	TDS mg/L	PHOSPHORUS P, Tot mg/L
1/12/93		k 6	20	k 0.1	14	172	0.07
2/23/93		k 6	k 10	0.1	14	171	k 0.03
3/16/93		k 6	k 10	k 0.1	18	193	k 0.03
5/11/93		k 6	k 10	k 0.1	12	178	k 0.03
8/2/93		k 6	k 10	k 0.1	11	188	k 0.03
9/8/93		k 6	k 10	k 0.1	11	149	k 0.03
10/27/93		k 6	k 10	k 0.1	12	159	k 0.03
11/17/93		k 6	k 10	k 0.1	15	170	k 0.03
2/2/94		k 6	k 10	k 0.1	17	183	k 0.03
3/2/94		k 6	k 10	k 0.1	12	182	k 0.03
3/15/94		k 6	k 10	k 0.1	14	181	k 0.03
4/26/94		k 6	k 10	k 0.1	13	172	0.04
6/1/94		k 6	k 10	k 0.1	12	171	k 0.03
8/1/94	20	k 6	k 10	k 0.1	11	162	k 0.03
8/31/94		k 6	k 10	k 0.1	11	153	k 0.03
10/3/94		k 6	10	k 0.1	13	175	k 0.03
11/9/94	88	9	20	k 0.1	15	179	0.06
1/18/95		k 6	k 10	k 0.1	11	187	k 0.03
3/7/95		k 6	20	k 0.1	14	185	k 0.03
4/26/95		k 6	k 10	k 0.1	12	169	k 0.03
5/18/95		k 6	k 10	k 0.1	13	180	k 0.03
6/15/95		k 6	k 10	k 0.1	11	165	k 0.03
7/26/95		k 6	k 10	k 0.1	12	165	k 0.03
8/29/95		k 6	k 10	k 0.1	11	165	k 0.03
9/26/95		k 6	k 10	k 0.1	13	174	k 0.03
10/24/95		k 6	k 10	k 0.1	12	170	k 0.03
11/14/95		k 6	10	k 0.1	13	165	k 0.03
12/20/95		k 6	k 10	k 0.1	12	174	k 0.03
1/22/96	79	k 6	6.5	0.1	20	190	k 0.03
2/27/96	250	k 6	6.8	k 0.1	12	190	k 0.03
3/25/96	310	6.7	9.2	0.1	18	189	k 0.03
4/23/96	320	6.4	7.6	k 0.1	13		k 0.03
5/21/96	50	k 6	13	k 0.1	12	174	k 0.03
6/18/96				k 0.1	12	167	k 0.03
7/16/96	20	k 6	5	k 0.1	12	175	k 0.03
8/20/96	20	k 6	k 4.5	k 0.1	10	168	k 0.03
9/17/96	170	k 6	k 4.5	k 0.1	12	178	k 0.03
10/22/96	41	k 6	k 4.5	k 0.1	15	171	k 0.03
11/12/96	120	k 6	k 4.5	k 0.1	13	175	k 0.03
12/10/96	150	6.4	k 4.5	k 0.1	18	186	k 0.03
Count(93-96)	13	39	39	40	40	39	40
ND(93-96)	3	35	28	37	0	0	37
Average	126	6	9.76	0.1	13.2	174.4	0.032
Minimum	20.0	6	4.5	0.1	10.0	149.0	0.03
Maximum	320	9	20	0.1	20.0	193.0	0.07
Stand Dev	108	0.49	3.67	0	2	10	0.0079
CV	0.86	0.08	0.38	0	0.17	0.06	0.247
Geomean (93-96)	78.0	0.79	3.81	0.0097	12.98	174.06	0.0029

STORET SYSTEM RETRIEVAL FOR WHITING INTAKE
1993 - 1996

DATE		FLUORIDE F, Total mg/l
1/12/93		0.2
2/23/93		0.2
3/16/93		0.2
5/11/93		0.1
8/2/93		0.1
9/8/93	k	0.1
10/27/93		0.2
11/17/93		0.2
2/2/94		0.1
3/2/94	k	0.1
3/15/94		0.1
4/26/94		0.2
6/1/94		0.1
8/1/94		0.1
8/31/94	k	0.1
10/3/94		0.2
11/9/94		0.2
1/18/95		0.1
3/7/95		0.2
4/26/95		0.1
5/18/95		0.1
6/15/95		0.1
7/26/95		0.1
8/29/95		0.2
9/26/95		0.2
10/24/95		0.2
11/14/95		0.2
12/20/95		0.1
1/22/96		0.2
2/27/96		0.1
3/25/96		0.2
4/23/96		0.1
5/21/96		0.1
6/18/96		0.1
7/16/96		0.1
8/20/96		0.1
9/17/96		0.2
10/22/96		0.2
11/12/96		0.2
12/10/96		0.2
Count(93-96)		40
ND(93-96)		3
Average		0.148
Minimum		0.10
Maximum		0.20
Stand Dev		0.0506
CV		0.343
Geomean (93-96)		0.1382

STORET SYSTEM RETRIEVAL FOR WHITING INTAKE
1993 - 1996

NOTE:

1. In accordance with IDEM Office of Water Management 327 IAC 2-1,2-1.5, and 15 Regulations (February 13, 1997), Geomean calculations for parameters containing below detection level values used the following formula:
   (limit of detection) x (1- # of nondetects/ total # of values).
2. Data obtained from USGS/USEPA STORET database.
3. k = below methd detection level.

171410 LM W
41 40 45.0 087 29 17.0 2
WHITING PUBLIC WATER INTAKE CRIB
18089 INDIANA LAKE
LAKE MICHIGAN 084991
CALUMET-BURNS DITCH COMPLEX
21IND 04040001004 0004.240 ON
0000 FEET DEPTH

IMT/INTAKE/LAKE

PARAMETER				MEDIUM	RMK	NUMBER	MEAN	VARIANCE	STAN DEV	MAXIMUM	MINIMUM	BEG DATE	END DATE
00010	WATER	TEMP	CENT	WATER		98	11.28400	52.51700	7.246900	26.0	.0	82/01/26	91/01/16
00076	TURB	TRBIDMTR	HACH FTU	WATER		85	11.18000	192.4800	13.87400	88.0	.7	82/01/26	90/11/27
00095	CNDUCTVY	AT 25C	MICROMHO	WATER		96	265.9000	2709.100	52.04900	400	116	82/01/26	90/06/05
00300	DO		MG/L	WATER		14	10.85900	2.409600	1.552300	13.3	8.6	84/05/15	90/06/05
00310	BOD	5 DAY	MG/L	WATER		81	1.023500	.0088198	.0939140	1.7	1.0	82/01/26	93/08/02
00335	COD	LOWLEVEL	MG/L	WATER		124	8.491900	9.845500	3.137800	20.0	4.0	82/01/26	93/11/17
00400	PH		SU	WATER		89	7.917800	.1007600	.3174300	8.50	6.40	82/01/26	90/06/05
00403	PH	LAB	SU	WATER		125	7.864800	.0665010	.2578800	8.5	6.8	82/01/26	93/11/17
00410	T ALK	CACO3	MG/L	WATER		125	113.2100	28.01600	5.293000	141	94	82/01/26	93/11/17
00500	RESIDUE	TOTAL	MG/L	WATER		122	191.0300	4580.900	67.68200	863	17	82/01/26	93/11/17
00530	RESIDUE	TOT NFLT	MG/L	WATER		45	28.06700	2878.600	53.65300	219	1	82/01/26	92/05/19
00556	OIL-GRSE	FREON-GR	MG/L	WATER		44	3.011400	2.083800	1.443600	6.70	1.00	82/01/26	89/12/12
00610	NH3+NH4-	N TOTAL	MG/L	WATER		124	.1008900	.0002276	.0150860	.200	.010	82/01/26	93/11/17
00625	TOT KJEL	N	MG/L	WATER		124	.2887900	.0081529	.0902930	.700	.100	82/01/26	93/11/17
00630	NO2&NO3	N-TOTAL	MG/L	WATER		124	.3741900	.1300600	.3606400	4.00	.10	82/01/26	93/11/17
00665	PHOS-TOT		MG/L P	WATER		124	.0513710	.0397290	.1993200	2.250	.030	82/01/26	93/11/17
00680	T ORG C	C	MG/L	WATER		38	3.165800	1.805000	1.343500	9.2	1.5	82/01/26	85/06/20
00720	CYANIDE	CN-TOT	MG/L	WATER		123	.0054959	.0000184	.0042950	.050	.005	82/01/26	93/11/17
00900	TOT HARD	CACO3	MG/L	WATER		125	143.8700	80.10500	8.950100	176	124	82/01/26	93/11/17
00910	CALCIUM	CACO3	MG/L	WATER		80	94.52500	50.20700	7.085700	130.0	74.0	85/11/21	92/12/15
00916	CALCIUM	CA-TOT	MG/L	WATER		2	95.00000	2.000000	1.414200	96.0	94.0	93/08/02	93/11/17
00920	MGNSIUM	CACO3	MG/L	WATER		37	51.05400	126.3900	11.24200	76.0	20.0	85/11/21	89/05/23
00929	SODIUM	NA,TOT	MG/L	WATER		124	6.882200	1.696400	1.302500	14.00	4.80	82/01/26	93/08/02
00937	PTSSIUM	K,TOT	MG/L	WATER		43	1.704700	.3533300	.5944100	5.00	1.20	82/01/26	85/12/19
00940	CHLORIDE	TOTAL	MG/L	WATER		125	11.65200	3.936400	1.984100	22	5	82/01/26	93/11/17
00945	SULFATE	SO4-TOT	MG/L	WATER		122	24.95100	6.329000	2.515800	32	19	82/01/26	93/11/17
00951	FLUORIDE	F,TOTAL	MG/L	WATER		125	.1360000	.0028063	.0529740	.40	.10	82/01/26	93/11/17
00955	SILICA	DISOLVED	MG/L	WATER		112	1.444700	8.006800	2.829600	30.0	.1	82/06/10	93/11/17
01002	ARSENIC	AS,TOT	UG/L	WATER		123	.9382100	.0340280	.1844700	2	.6	82/01/26	93/08/02
01007	BARIUM	BA,TOT	UG/L	WATER		77	19.81800	2.808900	1.676000	23	10	86/05/22	93/08/02
01012	BERYLIUM	BE,TOT	UG/L	WATER		13	1.876900	.0902570	.3004300	2.00	1.20	89/03/28	93/08/02
01027	CADMIUM	CD,TOT	UG/L	WATER		125	2.000000	.0000000	.0000000	2	2	82/01/26	93/08/02
01032	CHROMIUM	HEX-VAL	UG/L	WATER		123	10.00000	.0000000	.0000000	10	10	82/01/26	93/11/17
01034	CHROMIUM	CR,TOT	UG/L	WATER		124	10.85500	110.8400	10.52800	120	4	82/01/26	93/08/02
01042	COPPER	CU,TOT	UG/L	WATER		125	8.832000	115.4200	10.74300	58	4	82/01/26	93/08/02
01045	IRON	FE,TOT	UG/L	WATER		122	277.0200	98996.00	314.6400	1500	20	82/01/26	93/08/02
01046	IRON	FE,DISS	UG/L	WATER		51	45.88200	956.7100	30.93100	170	20	86/05/22	92/03/25
01051	LEAD	PB,TOT	UG/L	WATER		125	8.224000	12.74000	3.569300	41	6	82/01/26	93/08/02
01055	MANGNESE	MN	UG/L	WATER		125	40.00800	25650.00	160.1600	1800.0	6.0	82/01/26	93/08/02

171410 LM W
41 40 45.0 087 29 17.0 2
WHITING PUBLIC WATER INTAKE CRIB
18089 INDIANA LAKE
LAKE MICHIGAN 084991
CALUMET-BURNS DITCH COMPLEX
21IND 04040001004 0004.240 ON
0000 FEET DEPTH

/NTRTMT/INTAKE/LAKE

PARAMETER			MEDIUM	RMK	NUMBER	MEAN	VARIANCE	STAN DEV	MAXIMUM	MINIMUM	BEG DATE	END DATE
01059	THALLIUM TL,TOTAL	UG/L	WATER		13	18.76900	19.69300	4.437700	20	4	89/03/28	93/08/02
01067	NICKEL NI,TOTAL	UG/L	WATER		125	9.320000	221.5400	14.88400	100	4	82/01/26	93/08/02
01077	SILVER AG,TOT	UG/L	WATER		77	9.870100	.2461500	.4961300	10.0	8.0	86/05/22	93/08/02
01092	ZINC ZN,TOT	UG/L	WATER		125	13.60000	36.12900	6.010800	30	10	82/01/26	93/08/02
01097	ANTIMONY SB,TOT	UG/L	WATER		13	.6692300	.0056411	.0751080	.7	.5	89/03/28	93/08/02
01147	SELENIUM SE,TOT	UG/L	WATER		75	.5226700	.0425880	.2063700	1	.2	86/05/22	93/08/02
01503	ALPHA DISOLVED	PC/L	WATER		14	.6700000	2.663900	1.632200	6	-.7	82/03/16	84/12/21
01504	ALPHA-D ERROR	PC/L	WATER		14	1.146400	.5974700	.7729600	4	.3	82/03/16	84/12/21
01505	ALPHA SUSP	PC/L	WATER		14	.6421400	.9097800	.9538300	3	-.3	82/03/16	84/12/21
01506	ALPHA-S ERROR	PC/L	WATER		14	1.294300	.4281100	.6543000	3	.3	82/03/16	84/12/21
03503	BETA DISOLVED	PC/L	WATER		14	3.576400	7.398100	2.719900	9	.03	82/03/16	84/12/21
03504	BETA-D ERROR	PC/L	WATER		14	1.792100	.2870700	.5357900	3	.8	82/03/16	84/12/21
03505	BETA SUSP	PC/L	WATER		14	2.328600	5.456000	2.335800	7	-1	82/03/16	84/12/21
03506	BETA-S ERROR	PC/L	WATER		14	1.760000	.2565500	.5065000	3	.7	82/03/16	84/12/21
31501	TOT COLI MFIMENDO	/100ML	WATER		44	21803.00	1143E+07	106920.0	650000	10	82/01/26	86/02/20
31616	FEC COLI MFM-FCBR	/100ML	WATER		70	78.97200	96885.00	311.2600	1900	10	82/01/26	88/03/30
31648	E.COLI MTEC-MF	NO/100ML	WATER		50	316.6000	4490300	2119.000	15000	10	88/04/28	93/11/17
32101	DICLBRMT	TOTUG/L	WATER		9	1.000000	.0000000	.0000000	1.0	1.0	89/03/28	92/11/17
32102	CARBNTET	TOTUG/L	WATER		9	1.000000	.0000000	.0000000	1.0	1.0	89/03/28	92/11/17
32103	12DICLET	TOTUG/L	WATER		9	1.000000	.0000000	.0000000	1.0	1.0	89/03/28	92/11/17
32104	BROMOFRM WHL-WTR	UG/L	WATER		9	1.000000	.0000000	.0000000	1.0	1.0	89/03/28	92/11/17
32105	CLDIBRMT	TOTUG/L	WATER		9	1.000000	.0000000	.0000000	1.0	1.0	89/03/28	92/11/17
32106	CHLRFORM	TOTUG/L	WATER		9	1.000000	.0000000	.0000000	1.0	1.0	89/03/28	92/11/17
32730	PHENOLS TOTAL	UG/L	WATER		123	5.105700	.4559600	.6752500	10	5	82/01/26	93/11/17
32732	PHENOLS	DIS UG/L	WATER		8	4.200000	.0000000	.0000000	4.20	4.20	89/03/28	92/04/21
34010	TOLUENE	TOT UG/L	WATER		9	1.500000	.0000000	.0000000	1.50	1.50	89/03/28	92/11/17
34030	BENZENE	TOT UG/L	WATER		9	1.000000	.0000000	.0000000	1.00	1.00	89/03/28	92/11/17
34200	ACENAPHT HYLENE	TOTWUG/L	WATER		10	1.900000	8.100000	2.846100	10.000	1.000	89/03/28	92/11/17
34205	ACENAPHT HENE	TOTWUG/L	WATER		10	1.900000	8.100000	2.846100	10.000	1.000	89/03/28	92/11/17
34220	ANTHRACE NE	TOTWUG/L	WATER		10	1.900000	8.100000	2.846100	10.000	1.000	89/03/28	92/11/17
34230	BENZBFLU ORANT TO	TAL UG/L	WATER		10	3.250000	5.625000	2.371700	10.000	2.500	89/03/28	92/11/17
34242	BENZO(K) FLUORANT	TOTWUG/L	WATER		10	3.250000	5.625000	2.371700	10.000	2.500	89/03/28	92/11/17
34247	BENZO(A) PYRENE	TOTWUG/L	WATER		10	4.150000	4.225000	2.055500	10.000	3.500	89/03/28	92/11/17
34259	DELTABHC	TOTUG/L	WATER		10	.0200000	.0000000	.0000000	.020	.020	89/03/28	92/11/17
34273	BIS2CHLO ROETHYLE	TOTWUG/L	WATER		10	2.350000	7.225000	2.687900	10.000	1.500	89/03/28	92/11/17
34278	BIS2CHLO ROETHOXY	TOTWUG/L	WATER		10	2.350000	7.225000	2.687900	10.000	1.500	89/03/28	92/11/17
34283	BIS2CHLO ROISOPRO	TOTWUG/L	WATER		9	4.500000	.0000000	.0000000	4.500	4.500	89/03/28	92/04/21
34292	NBB PHTH TOTAL	UG/L	WATER		10	2.800000	6.400000	2.529800	10.000	2.000	89/03/28	92/11/17
34301	CHLOROBE NZENE	TOTWUG/L	WATER		9	1.000000	.0000000	.0000000	1.000	1.000	89/03/28	92/11/17

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WHITING PUBLIC WATER INTAKE CRIB
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PARAMETER		MEDIUM	RMK	NUMBER	MEAN	VARIANCE	STAN DEV	MAXIMUM	MINIMUM	BEG DATE	END DATE
34320 CHRYSENE	TOTWUG/L	WATER		10	4.150000	4.225000	2.055500	10.000	3.500	89/03/28	92/11/17
34336 DIETHYLP HTHALATE	TOTWUG/L	WATER		10	1.900000	8.100000	2.846100	10.000	1.000	89/03/28	92/11/17
34341 DIMETHYL PHTHALAT	TOTWUG/L	WATER		10	1.900000	8.100000	2.846100	10.000	1.000	89/03/28	92/11/17
34346 12DIPHEN YLHYDRAZ	TOTWUG/L	WATER		10	2.800000	6.400000	2.529800	10.000	2.000	89/03/28	92/11/17
34376 FLUORANT HENE	TOTWUG/L	WATER		10	1.900000	8.100000	2.846100	10.000	1.000	89/03/28	92/11/17
34381 FLUORENE	TOTWUG/L	WATER		10	1.900000	8.100000	2.846100	10.000	1.000	89/03/28	92/11/17
34386 HEXACHLO ROCYCLOP	TOTWUG/L	WATER		10	4.600000	3.600000	1.897400	10.000	4.000	89/03/28	92/11/17
34396 HEXACHLO ROETHANE	TOTWUG/L	WATER		10	4.600000	3.600000	1.897400	10.000	4.000	89/03/28	92/11/17
34403 INDENO(1 23CD)PYR	TOTWUG/L	WATER		10	4.150000	4.225000	2.055500	10.000	3.500	89/03/28	92/11/17
34408 ISPHRONE	TOTUG/L	WATER		10	1.900000	8.100000	2.846100	10.000	1.000	89/03/28	92/11/17
34423 METHYLEN ECHLORID	TOTWUG/L	WATER		9	6.000000	9.000000	3.000000	14.000	5.000	89/03/28	92/11/17
34428 NITROSOD IPROPYLA	TOTWUG/L	WATER		10	6.400000	1.600000	1.264900	10.000	6.000	89/03/28	92/11/17
34447 NITROBEN ZENE	TOTWUG/L	WATER		10	3.250000	5.625000	2.371700	10.000	2.500	89/03/28	92/11/17
34461 PHENANTH RENE	TOTWUG/L	WATER		9	1.000000	.0000000	.0000000	1.000	1.000	89/03/28	92/04/21
34469 PYRENE	TOTWUG/L	WATER		10	1.900000	8.100000	2.846100	10.000	1.000	89/03/28	92/11/17
34475 TETRACHL OROETHYL	TOTWUG/L	WATER		9	1.000000	.0000000	.0000000	1.000	1.000	89/03/28	92/11/17
34488 TRICHLOR OFLUOROM	TOTWUG/L	WATER		9	1.000000	.0000000	.0000000	1.000	1.000	89/03/28	92/11/17
34496 11DICHLO ROETHANE	TOTWUG/L	WATER		9	1.000000	.0000000	.0000000	1.000	1.000	89/03/28	92/11/17
34501 11DICHLO ROETHYLE	TOTWUG/L	WATER		9	1.000000	.0000000	.0000000	1.000	1.000	89/03/28	92/11/17
34506 111TRICH LOROETHA	TOTWUG/L	WATER		9	1.000000	.0000000	.0000000	1.000	1.000	89/03/28	92/11/17
34511 112TRICH LOROETHA	TOTWUG/L	WATER		9	1.000000	.0000000	.0000000	1.000	1.000	89/03/28	92/11/17
34516 1122TETR ACHLOROE	TOTWUG/L	WATER		9	1.000000	.0000000	.0000000	1.000	1.000	89/03/28	92/11/17
34521 BENZO(GH I)PERYLE	TOTWUG/L	WATER		10	4.150000	4.225000	2.055500	10.000	3.500	89/03/28	92/11/17
34526 BENZO(A) ANTHRACE	TOTWUG/L	WATER		10	3.700000	4.900000	2.213600	10.000	3.000	89/03/28	92/11/17
34536 12DICHLO ROBENZEN	TOTWUG/L	WATER		10	1.900000	8.100000	2.846100	10.000	1.000	89/03/28	92/11/17
34541 12DICHLO ROPROPAN	TOTWUG/L	WATER		9	1.000000	.0000000	.0000000	1.000	1.000	89/03/28	92/11/17
34546 12DICHLO ROETHENE	TOTWUG/L	WATER		9	1.000000	.0000000	.0000000	1.000	1.000	89/03/28	92/11/17
34551 124TRICH LOROBENZ	TOTWUG/L	WATER		10	2.800000	6.400000	2.529800	10.000	2.000	89/03/28	92/11/17
34556 DIBENZ(A H)ANTHRA	TOTWUG/L	WATER		10	4.150000	4.225000	2.055500	10.000	3.500	89/03/28	92/11/17
34566 13DICHLO ROBENZEN	TOTWUG/L	WATER		10	2.800000	6.400000	2.529800	10.000	2.000	89/03/28	92/11/17
34571 14DICHLO ROBENZEN	TOTWUG/L	WATER		10	1.900000	8.100000	2.846100	10.000	1.000	89/03/28	92/11/17
34581 2CHLORON APHTHALE	TOTWUG/L	WATER		10	1.900000	8.100000	2.846100	10.000	1.000	89/03/28	92/11/17
34586 2CHLOROP HENOL	TOTWUG/L	WATER		10	4.420000	3.844100	1.960600	10.000	3.800	89/03/28	92/11/17
34591 2NITROPH ENOL	TOTWUG/L	WATER		10	1.900000	8.100000	2.846100	10.000	1.000	89/03/28	92/11/17
34596 DINOCTPH	TOTUG/L	WATER		10	16.75000	1035.000	32.17200	98.000	1.500	89/03/28	92/11/17
34601 24DICHLO ROPHENOL	TOTWUG/L	WATER		10	5.320000	2.704100	1.644400	10.000	4.800	89/03/28	92/11/17
34606 24DIMETH YLPHENOL	TOTWUG/L	WATER		10	5.320000	2.704100	1.644400	10.000	4.800	89/03/28	92/11/17
34611 24DINITR OTOLUENE	TOTWUG/L	WATER		10	2.800000	6.400000	2.529800	10.000	2.000	89/03/28	92/11/17
34616 24DINITR OPHENOL	TOTWUG/L	WATER		10	3.940000	54.75600	7.399700	25.000	1.600	89/03/28	92/11/17

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PARAMETER	MEDIUM	RMK	NUMBER	MEAN	VARIANCE	STAN DEV	MAXIMUM	MINIMUM	BEG DATE	END DATE
34621 246TRICH LOROPHEN TOTWUG/L	WATER		10	6.580000	1.444000	1.201700	10.000	6.200	89/03/28	92/11/17
34626 26DINITR OTOLUENE TOTWUG/L	WATER		10	2.800000	6.400000	2.529800	10.000	2.000	89/03/28	92/11/17
34636 4BROMOPH ENYLPHEN TOTWUG/L	WATER		10	2.800000	6.400000	2.529800	10.000	2.000	89/03/28	92/11/17
34641 4CHLOROP HENYLPHE TOTWUG/L	WATER		10	2.350000	7.225000	2.687900	10.000	1.500	89/03/28	92/11/17
34646 4NITROPH ENOL TOTWUG/L	WATER		10	7.360000	38.41600	6.198100	25.000	5.400	89/03/28	92/11/17
34696 NAPTHALE NE T OTWUG/L	WATER		10	1.900000	8.100000	2.846100	10.000	1.000	89/03/28	92/11/17
34699 T1,3-DCP TOT WAT UG/L	WATER		9	1.000000	.0000000	.0000000	1.000	1.000	89/03/28	92/11/17
34704 C1,3-DCP TOT WAT UG/L	WATER		9	1.000000	.0000000	.0000000	1.000	1.000	89/03/28	92/11/17
34705 C1,3-DCP DISS WAT UG/L	WATER		1	1.000000			1.000	1.000	89/03/28	89/03/28
39032 PCP TOT UG/L	WATER		10	2.620000	6.724000	2.593100	10.000	1.800	89/03/28	92/11/17
39100 B2ETHHXL PHTHALAT TOT UG/L	WATER		10	23.18000	1450.300	38.08300	110.000	1.500	89/03/28	92/11/17
39110 DNB PHTH TOTAL UG/L	WATER		10	1.370000	.9023300	.9499100	4.000	1.000	89/03/28	92/11/17
39180 TRICHLOR ETHYLENE TOT UG/L	WATER		9	1.000000	.0000000	.0000000	1.000	1.000	89/03/28	92/11/17
39330 ALDRIN TOT UG/L	WATER		10	.0200000	.0000000	.0000000	.020	.020	89/03/28	92/11/17
39337 ALPHABHC TOTUG/L	WATER		10	.0100000	.0000000	.0000000	.010	.010	89/03/28	92/11/17
39338 BETA BHC TOTUG/L	WATER		10	.0300000	.0000000	.0000000	.030	.030	89/03/28	92/11/17
39340 GAMMABHC LINDANE TOT.UG/L	WATER		10	.0100000	.0000000	.0000000	.010	.010	89/03/28	92/11/17
39350 CHLRDANE TECH&MET TOT UG/L	WATER		10	.5000000	.0000000	.0000000	.500	.500	89/03/28	92/11/17
39360 DDD WHL SMPL UG/L	WATER		10	.0500000	.0000000	.0000000	.050	.050	89/03/28	92/11/17
39365 DDE WHL SMPL UG/L	WATER		10	.0500000	.0000000	.0000000	.050	.050	89/03/28	92/11/17
39370 DDT WHL SMPL UG/L	WATER		10	.1000000	.0000000	.0000000	.100	.100	89/03/28	92/11/17
39380 DIELDRIN TOTUG/L	WATER		10	.0500000	.0000000	.0000000	.050	.050	89/03/28	92/11/17
39388 ENDOSULN WHL SMPL UG/L	WATER		10	.0400000	.0000000	.0000000	.040	.040	89/03/28	92/11/17
[illegible]0 ENDRIN TOT UG/L	WATER		10	.0800000	.0000000	.0000000	.080	.080	89/03/28	92/11/17
[illegible]0 TOXAPHEN TOTUG/L	WATER		10	2.000000	.0000000	.0000000	2.000	2.000	89/03/28	92/11/1[illegible]
[illegible]410 HEPTCHLR TOTUG/L	WATER		10	.0200000	.0000000	.0000000	.020	.020	89/03/28	92/11/17
39420 HPCHLREP TOTUG/L	WATER		10	.0200000	.0000000	.0000000	.020	.020	89/03/28	92/11/17
39480 MTHXYCLR WHL SMPL UG/L	WATER		10	.2000000	.0000000	.0000000	.200	.200	89/03/28	92/11/17
39488 PCB-1221 TOTUG/L	WATER		10	.5000000	.0000000	.0000000	.500	.500	89/03/28	92/11/17
39492 PCB-1232 TOTUG/L	WATER		10	.5000000	.0000000	.0000000	.500	.500	89/03/28	92/11/17
39496 PCB-1242 TOTUG/L	WATER		10	.5000000	.0000000	.0000000	.500	.500	89/03/28	92/11/17
39500 PCB-1248 TOTUG/L	WATER		10	.5000000	.0000000	.0000000	.500	.500	89/03/28	92/11/17
39504 PCB-1254 TOTUG/L	WATER		10	.8000000	.0666670	.2582000	1.000	.500	89/03/28	92/11/17
39508 PCB-1260 TOTUG/L	WATER		10	.8000000	.0666670	.2582000	1.000	.500	89/03/28	92/11/17
39700 HCB TOT UG/L	WATER		10	7.180000	39.20400	6.261300	25.000	5.200	89/03/28	92/11/17
39702 HEXCLBD TOT UG/L	WATER		10	3.700000	4.900000	2.213600	10.00	3.00	89/03/28	92/11/17
47501 WEATHER SAMPLING CODE	WATER		61	29512.00	3608E+05	18995.00	81834	10014	86/05/22	92/07/27
70300 RESIDUE DISS-180 C MG/L	WATER		79	171.7900	1076.600	32.81100	430	82	85/12/19	93/11/17
71900 MERCURY HG,TOTAL UG/L	WATER		125	.1200000	.0390320	.1975700	2.3	.1	82/01/26	93/08/02

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	PARAMETER	MEDIUM	RMK	NUMBER	MEAN	VARIANCE	STAN DEV	MAXIMUM	MINIMUM	BEG DATE	END DATE
74041	WQF SAMPLE UPDATED	WATER		88	902100.0	5189E+05	22780.00	940518	861001	85/08/22	93/11/17
77089	ANILINE TOTAL UG/L	WATER		10	2.350000	7.225000	2.687900	10.000	1.500	89/03/28	92/11/17
77147	BNZYLALC TOTAL UG/L	WATER		10	3.250000	5.625000	2.371700	10.000	2.500	89/03/28	92/11/17
77247	BENZOICA TOTAL UG/L	WATER		10	2.530000	6.889000	2.624700	10.000	1.700	89/03/28	92/11/17
77416	2MNAPTHA TOTAL UG/L	WATER		10	1.900000	8.100000	2.846100	10.000	1.000	89/03/28	92/11/17
77571	CARBAZOL TOTAL UG/L	WATER		10	1.900000	8.100000	2.846100	10.000	1.000	89/03/28	92/11/17
77687	245TCLPH TOTAL UG/L	WATER		10	4.840000	50.17600	7.083500	25.000	2.600	89/03/28	92/11/17
78113	ETH BENZ WH WTR UG/L	WATER		9	2.000000	.0000000	.0000000	2.00	2.00	89/03/28	92/11/17
78300	3-NITRO ANILINE TOT UG/L	WATER		10	4.750000	50.62500	7.115100	25.000	2.500	89/03/28	92/11/17
81302	DIBENZO FURAN TOT UG/L	WATER		10	1.900000	8.100000	2.846100	10.000	1.000	89/03/28	92/11/17
81551	XYLENE TOT UG/L	WATER		9	9.000000	.0000000	.0000000	9.000	9.000	89/03/28	92/11/17
81552	ACETONE TOT UG/L	WATER		9	20.00000	.0000000	.0000000	20.000	20.000	89/03/28	92/11/17
81595	MTH ETH KETONE TOT UG/L	WATER		9	8.422200	43.80500	6.618500	26.000	6.000	89/03/28	92/11/17
81596	MTHISOBU KETONE TOT UG/L	WATER		9	3.000000	.0000000	.0000000	3.000	3.000	89/03/28	92/11/17
81648	PCB 1016 /1242 TOT UG/L	WATER		10	.5000000	.0000000	.0000000	.500	.500	89/03/28	92/11/17
81649	PCB-1262 TOT UG/L	WATER		8	.7500000	.0714290	.2672600	1.000	.500	89/03/28	92/11/1[illegible]
82623	ENDOSLFN -SO4 TOT REC UG/L	WATER		10	.1400000	.0060001	.0774600	.2	.05	89/03/28	92/11/1[illegible]
82624	ENDOSLFN BETA TOT REC UG/L	WATER		10	.0800000	.0006666	.0258200	.1	.05	89/03/28	92/11/17
85810	12DICLR ETHL TRN EFF UG/L	WATER		1	1.000000			1.000	1.000	89/03/28	89/03/28

GROSS

0 1 TOTAL STATIONS PROCESSED

	STA BEG	STA END	# OF OBS	# OF SAMPLE	STA END-PERIOD OF RECD IN YRS =0	<.5	<3	>=3
<1975	0	0	0	0	0	0	0	0
1975	0	0	0	0	0	0	0	0
1976	0	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0
1978	0	0	0	0	0	0	0	0
1979	0	0	0	0	0	0	0	0
1980	0	0	0	0	0	0	0	0
1981	0	0	0	0	0	0	0	0
1982	1	0	427	12	0	0	0	0
1983	0	0	407	11	0	0	0	0
1984	0	0	501	14	0	0	0	0
1985	0	0	443	12	0	0	0	0
1986	0	0	474	12	0	0	0	0
1987	0	0	452	11	0	0	0	0
1988	0	0	511	13	0	0	0	0
1989	0	0	858	12	0	0	0	0
1990	0	0	708	11	0	0	0	0
1991	0	0	599	11	0	0	0	0
1992	0	0	500	10	0	0	0	0
1993	0	1	122	7	0	0	0	1
1994	0	0	0	0	0	0	0	0
TOTAL	1	1	6002	136	0	0	0	1

GROSS

1 TOTAL STATIONS PROCESSED

PARAMETER				MEDIUM	RMK	NUMBER	MEAN	VARIANCE	STAN DEV	MAXIMUM	MINIMUM	BEG DATE	END DATE
00010	WATER	TEMP	CENT	WATER		98	11.28400	52.51700	7.246900	26.0	.0	82/01/26	91/01/16
00076	TURB	TRBIDMTR	HACH FTU	WATER		85	11.18000	192.4800	13.87400	88.0	.7	82/01/26	90/11/27
00095	CNDUCTVY	AT 25C	MICROMHO	WATER		96	265.9000	2709.100	52.04900	400	116	82/01/26	90/06/05
00300	DO		MG/L	WATER		14	10.85900	2.409600	1.552300	13.3	8.6	84/05/15	90/06/05
00310	BOD	5 DAY	MG/L	WATER		81	1.023500	.0088198	.0939140	1.7	1.0	82/01/26	93/08/02
00335	COD	LOWLEVEL	MG/L	WATER		124	8.491900	9.845500	3.137800	20.0	4.0	82/01/26	93/11/17
00400	PH		SU	WATER		89	7.917800	.1007600	.3174300	8.50	6.40	82/01/26	90/06/05
00403	PH	LAB	SU	WATER		125	7.864800	.0665010	.2578800	8.5	6.8	82/01/26	93/11/17
00410	T ALK	CACO3	MG/L	WATER		125	113.2100	28.01600	5.293000	141	94	82/01/26	93/11/17
00500	RESIDUE	TOTAL	MG/L	WATER		122	191.0300	4580.900	67.68200	863	17	82/01/26	93/11/17
00530	RESIDUE	TOT NFLT	MG/L	WATER		45	28.06700	2878.600	53.65300	219	1	82/01/26	92/05/19
00556	OIL-GRSE	FREON-GR	MG/L	WATER		44	3.011400	2.083800	1.443600	6.70	1.00	82/01/26	89/12/12
00610	NH3+NH4-	N TOTAL	MG/L	WATER		124	.1008900	.0002276	.0150860	.200	.010	82/01/26	93/11/17
00625	TOT KJEL	N	MG/L	WATER		124	.2887900	.0081529	.0902930	.700	.100	82/01/26	93/11/17
00630	NO2&NO3	N-TOTAL	MG/L	WATER		124	.3741900	.1300600	.3606400	4.00	.10	82/01/26	93/11/17
00665	PHOS-TOT		MG/L P	WATER		124	.0513710	.0397290	.1993200	2.250	.030	82/01/26	93/11/17
00680	T ORG C	C	MG/L	WATER		38	3.165800	1.805000	1.343500	9.2	1.5	82/01/26	85/06/20
00720	CYANIDE	CN-TOT	MG/L	WATER		123	.0054959	.0000184	.0042950	.050	.005	82/01/26	93/11/17
00900	TOT HARD	CACO3	MG/L	WATER		125	143.8700	80.10500	8.950100	176	124	82/01/26	93/11/17
00910	CALCIUM	CACO3	MG/L	WATER		80	94.52500	50.20700	7.085700	130.0	74.0	85/11/21	92/12/15
00916	CALCIUM	CA-TOT	MG/L	WATER		2	95.00000	2.000000	1.414200	96.0	94.0	93/08/02	93/11/17
00920	MGNSIUM	CACO3	MG/L	WATER		37	51.05400	126.3900	11.24200	76.0	20.0	85/11/21	89/05/23
00929	SODIUM	NA,TOT	MG/L	WATER		124	6.882200	1.696400	1.302500	14.00	4.80	82/01/26	93/08/02
00937	PTSSIUM	K,TOT	MG/L	WATER		43	1.704700	.3533300	.5944100	5.00	1.20	82/01/26	85/12/19
00940	CHLORIDE	TOTAL	MG/L	WATER		125	11.65200	3.936400	1.984100	22	5	82/01/26	93/11/17
00945	SULFATE	SO4-TOT	MG/L	WATER		122	24.95100	6.329000	2.515800	32	19	82/01/26	93/11/17
00951	FLUORIDE	F,TOTAL	MG/L	WATER		125	.1360000	.0028063	.0529740	.40	.10	82/01/26	93/11/17
00955	SILICA	DISOLVED	MG/L	WATER		112	1.444700	8.006800	2.829600	30.0	.1	82/06/10	93/11/17
01002	ARSENIC	AS,TOT	UG/L	WATER		123	.9382100	.0340280	.1844700	2	.6	82/01/26	93/08/02
01007	BARIUM	BA,TOT	UG/L	WATER		77	19.81800	2.808900	1.676000	23	10	86/05/22	93/08/02
01012	BERYLIUM	BE,TOT	UG/L	WATER		13	1.876900	.0902570	.3004300	2.00	1.20	89/03/28	93/08/02
01027	CADMIUM	CD,TOT	UG/L	WATER		125	2.000000	.0000000	.0000000	2	2	82/01/26	93/08/02
01032	CHROMIUM	HEX-VAL	UG/L	WATER		123	10.00000	.0000000	.0000000	10	10	82/01/26	93/11/17
01034	CHROMIUM	CR,TOT	UG/L	WATER		124	10.85500	110.8400	10.52800	120	4	82/01/26	93/08/02
01042	COPPER	CU,TOT	UG/L	WATER		125	8.832000	115.4200	10.74300	58	4	82/01/26	93/08/02
01045	IRON	FE,TOT	UG/L	WATER		122	277.0200	98996.00	314.6400	1500	20	82/01/26	93/08/02
01046	IRON	FE,DISS	UG/L	WATER		51	45.88200	956.7100	30.93100	170	20	86/05/22	92/03/25
01051	LEAD	PB,TOT	UG/L	WATER		125	8.224000	12.74000	3.569300	41	6	82/01/26	93/08/02
01055	MANGNESE	MN	UG/L	WATER		125	40.00800	25650.00	160.1600	1800.0	6.0	82/01/26	93/08/02
01059	THALLIUM	TL,TOTAL	UG/L	WATER		13	18.76900	19.69300	4.437700	20	4	89/03/28	93/08/02
01067	NICKEL	NI,TOTAL	UG/L	WATER		125	9.320000	221.5400	14.88400	100	4	82/01/26	93/08/02
01077	SILVER	AG,TOT	UG/L	WATER		77	9.870100	.2461500	.4961300	10.0	8.0	86/05/22	93/08/02

GROSS

0 1 TOTAL STATIONS PROCESSED

0	PARAMETER			MEDIUM	RMK	NUMBER	MEAN	VARIANCE	STAN DEV	MAXIMUM	MINIMUM	BEG DATE	END DATE
01092	ZINC	ZN,TOT	UG/L	WATER		125	13.60000	36.12900	6.010800	30	10	82/01/26	93/08/02
01097	ANTIMONY	SB,TOT	UG/L	WATER		13	.6692300	.0056411	.0751080	.7	.5	89/03/28	93/08/02
01147	SELENIUM	SE,TOT	UG/L	WATER		75	.5226700	.0425880	.2063700	1	.2	86/05/22	93/08/02
01503	ALPHA	DISOLVED	PC/L	WATER		14	.6700000	2.663900	1.632200	6	-.7	82/03/16	84/12/21
01504	ALPHA-D	ERROR	PC/L	WATER		14	1.146400	.5974700	.7729600	4	.3	82/03/16	84/12/21
01505	ALPHA	SUSP	PC/L	WATER		14	.6421400	.9097800	.9538300	3	-.3	82/03/16	84/12/21
01506	ALPHA-S	ERROR	PC/L	WATER		14	1.294300	.4281100	.6543000	3	.3	82/03/16	84/12/21
03503	BETA	DISOLVED	PC/L	WATER		14	3.576400	7.398100	2.719900	9	.03	82/03/16	84/12/21
03504	BETA-D	ERROR	PC/L	WATER		14	1.792100	.2870700	.5357900	3	.8	82/03/16	84/12/21
03505	BETA	SUSP	PC/L	WATER		14	2.328600	5.456000	2.335800	7	-1	82/03/16	84/12/21
03506	BETA-S	ERROR	PC/L	WATER		14	1.760000	.2565500	.5065000	3	.7	82/03/16	84/12/21
31501	TOT COLI	MFIMENDO	/100ML	WATER		44	21803.00	1143E+07	106920.0	650000	10	82/01/26	86/02/20
31616	FEC COLI	MFM-FCBR	/100ML	WATER		70	78.97200	96885.00	311.2600	1900	10	82/01/26	88/03/30
31648	E.COLI	MTEC-MF	NO/100ML	WATER		50	316.6000	4490300	2119.000	15000	10	88/04/28	93/11/17
32101	DICLBRMT		TOTUG/L	WATER		9	1.000000	.0000000	.0000000	1.0	1.0	89/03/28	92/11/17
32102	CARBNTET		TOTUG/L	WATER		9	1.000000	.0000000	.0000000	1.0	1.0	89/03/28	92/11/17
32103	12DICLET		TOTUG/L	WATER		9	1.000000	.0000000	.0000000	1.0	1.0	89/03/28	92/11/17
32104	BROMOFRM	WHL-WTR	UG/L	WATER		9	1.000000	.0000000	.0000000	1.0	1.0	89/03/28	92/11/17
32105	CLDIBRMT		TOTUG/L	WATER		9	1.000000	.0000000	.0000000	1.0	1.0	89/03/28	92/11/17
32106	CHLRFORM		TOTUG/L	WATER		9	1.000000	.0000000	.0000000	1.0	1.0	89/03/28	92/11/17
32730	PHENOLS	TOTAL	UG/L	WATER		123	5.105700	.4559600	.6752500	10	5	82/01/26	93/11/17
32732	PHENOLS		DIS UG/L	WATER		8	4.200000	.0000000	.0000000	4.20	4.20	89/03/28	92/04/21
34010	TOLUENE		TOT UG/L	WATER		9	1.500000	.0000000	.0000000	1.50	1.50	89/03/28	92/11/17
34030	BENZENE		TOT UG/L	WATER		9	1.000000	.0000000	.0000000	1.00	1.00	89/03/28	92/11/17
34200	ACENAPHT	HYLENE	TOTWUG/L	WATER		10	1.900000	8.100000	2.846100	10.000	1.000	89/03/28	92/11/17
34205	ACENAPHT	HENE	TOTWUG/L	WATER		10	1.900000	8.100000	2.846100	10.000	1.000	89/03/28	92/11/17
34220	ANTHRACE	NE	TOTWUG/L	WATER		10	1.900000	8.100000	2.846100	10.000	1.000	89/03/28	92/11/17
34230	BENZBFLU	ORANT TO	TAL UG/L	WATER		10	3.250000	5.625000	2.371700	10.000	2.500	89/03/28	92/11/17
[illegible]242	BENZO(K)	FLUORANT	TOTWUG/L	WATER		10	3.250000	5.625000	2.371700	10.000	2.500	89/03/28	92/11/'
34247	BENZO(A)	PYRENE	TOTWUG/L	WATER		10	4.150000	4.225000	2.055500	10.000	3.500	89/03/28	92/11/17
34259	DELTABHC		TOTUG/L	WATER		10	.0200000	.0000000	.0000000	.020	.020	89/03/28	92/11/17
34273	BIS2CHLO	ROETHYLE	TOTWJG/L	WATER		10	2.350000	7.225000	2.687900	10.000	1.500	89/03/28	92/11/17
34278	BIS2CHLO	ROETHOXY	TOTWJG/L	WATER		10	2.350000	7.225000	2.687900	10.000	1.500	89/03/28	92/11/17
34283	BIS2CHLO	ROISOPRO	TOTWJG/L	WATER		9	4.500000	.0000000	.0000000	4.500	4.500	89/03/28	92/04/21
34292	NBB PHTH	TOTAL	UG/L	WATER		10	2.800000	6.400000	2.529800	10.000	2.000	89/03/28	92/11/17
34301	CHLOROBE	NZENE	TOTWJG/L	WATER		9	1.000000	.0000000	.0000000	1.000	1.000	89/03/28	92/11/17
34320	CHRYSENE		TOTWJG/L	WATER		10	4.150000	4.225000	2.055500	10.000	3.500	89/03/28	92/11/17
34336	DIETHYLP	HTHALATE	TOTWJG/L	WATER		10	1.900000	8.100000	2.846100	10.000	1.000	89/03/28	92/11/17
34341	DIMETHYL	PHTHALAT	TOTWJG/L	WATER		10	1.900000	8.100000	2.846100	10.000	1.000	89/03/28	92/11/17
34346	12DIPHEN	YLHYDRAZ	TOTWJG/L	WATER		10	2.800000	6.400000	2.529800	10.000	2.000	89/03/28	92/11/17
34376	FLUORANT	HENE	TOTWJG/L	WATER		10	1.900000	8.100000	2.846100	10.000	1.000	89/03/28	92/11/17
34381	FLUORENE		TOTWJG/L	WATER		10	1.900000	8.100000	2.846100	10.000	1.000	89/03/28	92/11/17

0 1 TOTAL STATIONS PROCESSED

0	PARAMETER	MEDIUM	RMK	NUMBER	MEAN	VARIANCE	STAN DEV	MAXIMUM	MINIMUM	BEG DATE	END DATE
34386	HEXACHLO ROCYCLOP TOTWUG/L	WATER		10	4.600000	3.600000	1.897400	10.000	4.000	89/03/28	92/11/17
34396	HEXACHLO ROETHANE TOTWUG/L	WATER		10	4.600000	3.600000	1.897400	10.000	4.000	89/03/28	92/11/17
34403	INDENO(1 23CD)PYR TOTWUG/L	WATER		10	4.150000	4.225000	2.055500	10.000	3.500	89/03/28	92/11/17
34408	ISPHRONE TOTUG/L	WATER		10	1.900000	8.100000	2.846100	10.000	1.000	89/03/28	92/11/17
34423	METHYLEN ECHLORID TOTWUG/L	WATER		9	6.000000	9.000000	3.000000	14.000	5.000	89/03/28	92/11/17
34428	NITROSOD IPROPYLA TOTWUG/L	WATER		10	6.400000	1.600000	1.264900	10.000	6.000	89/03/28	92/11/17
34447	NITROBEN ZENE TOTWUG/L	WATER		10	3.250000	5.625000	2.371700	10.000	2.500	89/03/28	92/11/17
34461	PHENANTH RENE TOTWUG/L	WATER		9	1.000000	.0000000	.0000000	1.000	1.000	89/03/28	92/04/21
34469	PYRENE TOTWUG/L	WATER		10	1.900000	8.100000	2.846100	10.000	1.000	89/03/28	92/11/17
34475	TETRACHL OROETHYL TOTWUG/L	WATER		9	1.000000	.0000000	.0000000	1.000	1.000	89/03/28	92/11/17
34488	TRICHLOR OFLUOROM TOTWUG/L	WATER		9	1.000000	.0000000	.0000000	1.000	1.000	89/03/28	92/11/17
34496	11DICHLO ROETHANE TOTWUG/L	WATER		9	1.000000	.0000000	.0000000	1.000	1.000	89/03/28	92/11/17
34501	11DICHLO ROETHYLE TOTWUG/L	WATER		9	1.000000	.0000000	.0000000	1.000	1.000	89/03/28	92/11/17
34506	111TRICH LOROETHA TOTWUG/L	WATER		9	1.000000	.0000000	.0000000	1.000	1.000	89/03/28	92/11/17
34511	112TRICH LOROETHA TOTWUG/L	WATER		9	1.000000	.0000000	.0000000	1.000	1.000	89/03/28	92/11/17
34516	1122TETR ACHLOROE TOTWUG/L	WATER		9	1.000000	.0000000	.0000000	1.000	1.000	89/03/28	92/11/17
34521	BENZO(GH I)PERYLE TOTWUG/L	WATER		10	4.150000	4.225000	2.055500	10.000	3.500	89/03/28	92/11/17
34526	BENZO(A) ANTHRACE TOTWUG/L	WATER		10	3.700000	4.900000	2.213600	10.000	3.000	89/03/28	92/11/17
34536	12DICHLO ROBENZEN TOTWUG/L	WATER		10	1.900000	8.100000	2.846100	10.000	1.000	89/03/28	92/11/17
34541	12DICHLO ROPROPAN TOTWUG/L	WATER		9	1.000000	.0000000	.0000000	1.000	1.000	89/03/28	92/11/17
34546	12DICHLO ROETHENE TOTWUG/L	WATER		9	1.000000	.0000000	.0000000	1.000	1.000	89/03/28	92/11/17
34551	124TRICH LOROBENZ TOTWUG/L	WATER		10	2.800000	6.400000	2.529800	10.000	2.000	89/03/28	92/11/17
34556	DIBENZ(A H)ANTHRA TOTWUG/L	WATER		10	4.150000	4.225000	2.055500	10.000	3.500	89/03/28	92/11/17
34566	13DICHLO ROBENZEN TOTWUG/L	WATER		10	2.800000	6.400000	2.529800	10.000	2.000	89/03/28	92/11/17
34571	14DICHLO ROBENZEN TOTWUG/L	WATER		10	1.900000	8.100000	2.846100	10.000	1.000	89/03/28	92/11/17
34581	2CHLORON APHTHALE TOTWUG/L	WATER		10	1.900000	8.100000	2.846100	10.000	1.000	89/03/28	92/11/17
34586	2CHLOROP HENOL TOTWUG/L	WATER		10	4.420000	3.844100	1.960600	10.000	3.800	89/03/28	92/11/17
34591	2NITROPH ENOL TOTWUG/L	WATER		10	1.900000	8.100000	2.846100	10.000	1.000	89/03/28	92/11/17
4596	DINOCTPH TOTUG/L	WATER		10	16.75000	1035.000	32.17200	98.000	1.500	89/03/28	92/11/17
34601	24DICHLO ROPHENOL TOTWUG/L	WATER		10	5.320000	2.704100	1.644400	10.000	4.800	89/03/28	92/11/17
34606	24DIMETH YLPHENOL TOTWUG/L	WATER		10	5.320000	2.704100	1.644400	10.000	4.800	89/03/28	92/11/17
34611	24DINITR OTOLUENE TOTWUG/L	WATER		10	2.800000	6.400000	2.529800	10.000	2.000	89/03/28	92/11/17
34616	24DINITR OPHENOL TOTWUG/L	WATER		10	3.940000	54.75600	7.399700	25.000	1.600	89/03/28	92/11/17
34621	246TRICH LOROPHEN TOTWUG/L	WATER		10	6.580000	1.444000	1.201700	10.000	6.200	89/03/28	92/11/17
34626	26DINITR OTOLUENE TOTWUG/L	WATER		10	2.800000	6.400000	2.529800	10.000	2.000	89/03/28	92/11/17
34636	4BROMOPH ENYLPHEN TOTWUG/L	WATER		10	2.800000	6.400000	2.529800	10.000	2.000	89/03/28	92/11/17
34641	4CHLOROP HENYLPHE TOTWUG/L	WATER		10	2.350000	7.225000	2.687900	10.000	1.500	89/03/28	92/11/17
34646	4NITROPH ENOL TOTWUG/L	WATER		10	7.360000	38.41600	6.198100	25.000	5.400	89/03/28	92/11/17
34696	NAPTHALE NE T OTWUG/L	WATER		10	1.900000	8.100000	2.846100	10.000	1.000	89/03/28	92/11/17
34699	T1,3-DCP TOT WAT UG/L	WATER		9	1.000000	.0000000	.0000000	1.000	1.000	89/03/28	92/11/17
34704	C1,3-DCP TOT WAT UG/L	WATER		9	1.000000	.0000000	.0000000	1.000	1.000	89/03/28	92/11/17
34705	C1,3-DCP DISS WAT UG/L	WATER		1	1.000000			1.000	1.000	89/03/28	89/03/28

PARAMETER	MEDIUM	RMK	NUMBER	MEAN	VARIANCE	STAN DEV	MAXIMUM	MINIMUM	BEG DATE	END DATE
39032 PCP TOT UG/L	WATER		10	2.620000	6.724000	2.593100	10.000	1.800	89/03/28	92/11/17
39100 B2ETHHXL PHTHALAT TOT UG/L	WATER		10	23.18000	1450.300	38.08300	110.000	1.500	89/03/28	92/11/17
39110 DNB PHTH TOTAL UG/L	WATER		10	1.370000	.9023300	.9499100	4.000	1.000	89/03/28	92/11/17
39180 TRICHLOR ETHYLENE TOT UG/L	WATER		9	1.000000	.0000000	.0000000	1.000	1.000	89/03/28	92/11/17
39330 ALDRIN TOT UG/L	WATER		10	.0200000	.0000000	.0000000	.020	.020	89/03/28	92/11/17
39337 ALPHABHC TOTUG/L	WATER		10	.0100000	.0000000	.0000000	.010	.010	89/03/28	92/11/17
39338 BETA BHC TOTUG/L	WATER		10	.0300000	.0000000	.0000000	.030	.030	89/03/28	92/11/17
39340 GAMMABHC LINDANE TOT.UG/L	WATER		10	.0100000	.0000000	.0000000	.010	.010	89/03/28	92/11/17
39350 CHLRDANE TECH&MET TOT UG/L	WATER		10	.5000000	.0000000	.0000000	.500	.500	89/03/28	92/11/17
39360 DDD WHL SMPL UG/L	WATER		10	.0500000	.0000000	.0000000	.050	.050	89/03/28	92/11/17
39365 DDE WHL SMPL UG/L	WATER		10	.0500000	.0000000	.0000000	.050	.050	89/03/28	92/11/17
39370 DDT WHL SMPL UG/L	WATER		10	.1000000	.0000000	.0000000	.100	.100	89/03/28	92/11/17
39380 DIELDRIN TOTUG/L	WATER		10	.0500000	.0000000	.0000000	.050	.050	89/03/28	92/11/17
39388 ENDOSULN WHL SMPL UG/L	WATER		10	.0400000	.0000000	.0000000	.040	.040	89/03/28	92/11/17
39390 ENDRIN TOT UG/L	WATER		10	.0800000	.0000000	.0000000	.080	.080	89/03/28	92/11/17
39400 TOXAPHEN TOTUG/L	WATER		10	2.000000	.0000000	.0000000	2.000	2.000	89/03/28	92/11/17
39410 HEPTCHLR TOTUG/L	WATER		10	.0200000	.0000000	.0000000	.020	.020	89/03/28	92/11/17
39420 HPCHLREP TOTUG/L	WATER		10	.0200000	.0000000	.0000000	.020	.020	89/03/28	92/11/17
39480 MTHXYCLR WHL SMPL UG/L	WATER		10	.2000000	.0000000	.0000000	.200	.200	89/03/28	92/11/17
39488 PCB-1221 TOTUG/L	WATER		10	.5000000	.0000000	.0000000	.500	.500	89/03/28	92/11/17
39492 PCB-1232 TOTUG/L	WATER		10	.5000000	.0000000	.0000000	.500	.500	89/03/28	92/11/17
39496 PCB-1242 TOTUG/L	WATER		10	.5000000	.0000000	.0000000	.500	.500	89/03/28	92/11/17
39500 PCB-1248 TOTUG/L	WATER		10	.5000000	.0000000	.0000000	.500	.500	89/03/28	92/11/17
39504 PCB-1254 TOTUG/L	WATER		10	.8000000	.0666670	.2582000	1.000	.500	89/03/28	92/11/17
39508 PCB-1260 TOTUG/L	WATER		10	.8000000	.0666670	.2582000	1.000	.500	89/03/28	92/11/17
39700 HCB TOT UG/L	WATER		10	7.180000	39.20400	6.261300	25.000	5.200	89/03/28	92/11/17
39702 HEXCLBD TOT UG/L	WATER		10	3.700000	4.900000	2.213600	10.00	3.00	89/03/28	92/11/17
47[illegible] WEATHER SAMPLING CODE	WATER		61	29512.00	3608E+05	18995.00	81834	10014	86/05/22	92/07/27
[illegible] RESIDUE DISS-180 C MG/L	WATER		79	171.7900	1076.600	32.81100	430	82	85/12/19	93/11/17
7[illegible] MERCURY HG,TOTAL UG/L	WATER		125	.1200000	.0390320	.1975700	2.3	.1	82/01/26	93/08/02
74041 WQF SAMPLE UPDATED	WATER		88	902100.0	5189E+05	22780.00	940518	861001	85/08/22	93/11/17
77089 ANILINE TOTAL UG/L	WATER		10	2.350000	7.225000	2.687900	10.000	1.500	89/03/28	92/11/17
77147 BNZYLALC TOTAL UG/L	WATER		10	3.250000	5.625000	2.371700	10.000	2.500	89/03/28	92/11/17
77247 BENZOICA TOTAL UG/L	WATER		10	2.530000	6.889000	2.624700	10.000	1.700	89/03/28	92/11/17
77416 2MNAPTHA TOTAL UG/L	WATER		10	1.900000	8.100000	2.846100	10.000	1.000	89/03/28	92/11/17
77571 CARBAZOL TOTAL UG/L	WATER		10	1.900000	8.100000	2.846100	10.000	1.000	89/03/28	92/11/17
77687 245TCLPH TOTAL UG/L	WATER		10	4.840000	50.17600	7.083500	25.000	2.600	89/03/28	92/11/17
78113 ETH BENZ WH WTR UG/L	WATER		9	2.000000	.0000000	.0000000	2.00	2.00	89/03/28	92/11/17
78300 3-NITRO ANILINE TOT UG/L	WATER		10	4.750000	50.62500	7.115100	25.000	2.500	89/03/28	92/11/17
81302 DIBENZO FURAN TOT UG/L	WATER		10	1.900000	8.100000	2.846100	10.000	1.000	89/03/28	92/11/17
81551 XYLENE TOT UG/L	WATER		9	9.000000	.0000000	.0000000	9.000	9.000	89/03/28	92/11/17
81552 ACETONE TOT UG/L	WATER		9	20.00000	.0000000	.0000000	20.000	20.000	89/03/28	92/11/17

STORET RETRIEVAL DATE 94/06/28 PGM=INVENT

GROSS

1 TOTAL STATIONS PROCESSED

PARAMETER	MEDIUM	RMK	NUMBER	MEAN	VARIANCE	STAN DEV	MAXIMUM	MINIMUM	BEG DATE	END DATE
81595 MTH ETH KETONE TOT UG/L	WATER		9	8.422200	43.80500	6.618500	26.000	6.000	89/03/28	92/11/17
81596 MTHISOBU KETONE TOT UG/L	WATER		9	3.000000	.0000000	.0000000	3.000	3.000	89/03/28	92/11/17
81648 PCB 1016 /1242 TOT UG/L	WATER		10	.5000000	.0000000	.0000000	.500	.500	89/03/28	92/11/17
81649 PCB-1262 TOT UG/L	WATER		8	.7500000	.0714290	.2672600	1.000	.500	89/03/28	92/11/17
82623 ENDOSLFN -SO4 TOT REC UG/L	WATER		10	.1400000	.0060001	.0774600	.2	.05	89/03/28	92/11/17
82624 ENDOSLFN BETA TOT REC UG/L	WATER		10	.0800000	.0006666	.0258200	.1	.05	89/03/28	92/11/17
85810 12DICLR ETHL TRN EFF UG/L	WATER		1	1.000000			1.000	1.000	89/03/28	89/03/28

HAT'S ALL FOLKS

STORET RETRIEVAL DATE 94/06/28

1

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8

ATTACHMENT 8

SOUTHERN END OF LAKE MICHIGAN
REPRESENTATIVE FISHERIES

Table 18. Fish Species Collected from the Grand Calumet River, Indiana Harbor Canal, Indiana Harbor, and southwestern Lake Michigan During Various Sampling Activities.

		GCR/IHC	Harbor	Lake
Alewife	*Alosa pseudoharengus*	+	+	+
Gizzard shad	*Dorosoma cepedianum*	+	+	+
Steelhead trout	*Salmo gairdneri*	+	+	+
Brown trout	*S. trutta*		+	+
Lake trout	*Salvelinus namaycush*			+
Chinook salmon	*Oncorhynchus tshawytscha*	+	+	+
Coho salmon	*O. kisutch*	+		+
Lake whitefish	*Coregonus clupeaformis*			+
Rainbow smelt	*Osmerus mordax*	+		+
Central mudminnow	*Umbra limi*	+		
Goldfish	*Carassius auratus*	+	+	
Carp	*Cyprinus carpio*	+	+	+
Goldfish x Carp hybrid		+		
Rudd	*Scardinius erythrophthalmus*	+	+	
Golden shiner	*Notemigonus crysoleucas*	+		
Emerald shiner	*Notropis atherinoides*	+	+	
Spottail shiner	*N. hudsonius*	+	+	+
Blacknose shiner	*N. heterolepis*		+	
Spotfin shiner	*N. spilopterus*	+		
Sand shiner	*N. stramineus*		+	+
Bluntnose minnow	*Pimephales notatus*	+	+	
Fathead minnow	*P. promelas*	+	+	
Bullhead minnow	*P. vigilax*	+		
Longnose dace	*Rhinichthys cataractae*			+
White sucker	*Catostomus commersoni*			+
Longnose sucker	*C. catostomus*			+
Silver redhorse	*Moxostoma anisurum*		+	
Golden redhorse	*M. erythrurum*	+		
Channel catfish	*Ictalurus punctatus*			+
Black bullhead	*Ameiurus melas*	+		
Trout-perch	*Percopsis omiscomaycus*			+

Burbot	*Lota lota*			+
Rock bass	*Ambloplites rupestris*		+	+
Green sunfish	*Lepomis cyanellus*	+		
Pumpkinseed	*L. gibbosus*	+	+	+
Orangespotted sunfish	*L. humilis*		+	
Bluegill	*L. macrochirus*	+		
Smallmouth bass	*Micropterus dolomieui*		+	+
Largemouth bass	*M. salmoides*	+		
Black crappie	*Pomoxis nigromaculatus*		+	+
Yellow perch	*Perca flavescens*	+	+	+
Johnny darter	*Etheostoma nigrum*		+	+
Freshwater drum	*Aplodinotus grunniens*		+	+
Mottled sculpin	*Cottus bairdi*		+	+
Slimy sculpin	*C. cognatus*			+
Threespine stickelback	*Gasterosteus aculeatus*		+	

Sources: Indiana Department of Natural Resources studies; Polls and Dennison 1984; IDEM 1988; Risatti and Ross 1989; Simon *et al.* 1989; Simon 1992; Sobiech *et al.* 1994; Chicago District Corps sampling in 1994, 1995, and 1996

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ATTACHMENT 9

1997 INDIANA ENDANGERED, THREATENED, AND RARE SPECIES LISTS

1995 MICHIGAN NON-INDIGENOUS AQUATIC NUISANCE SPECIES STATE MANAGEMENT PLAN: EXECUTIVE SUMMARY

ENDANGERED. THREATENED AND RARE VERTEBRATES AND INVERTEBRATES. INDIANA
INDIANA NATURAL HERITAGE DATA CENTER

ELCODE:...	SPECIES NAME:......................	COMMON NAME:......................	SPROT:	USESA:	SRANK:.	GRANK
** Mammal						
AMALE01010	BOS BISON	AMERICAN BISON	SX	**	SX	G4
AMAJA01030	CANIS LUPUS	GRAY WOLF	SX	LELT	SX	G4
AMAJA01020	CANIS RUFUS	RED WOLF	SX	LEXN	SX	G1
AMALC01010	CERVUS ELAPHUS	WAPITI OR ELK	SX	**	SX	G5
AMABB05010	CONDYLURA CRISTATA	STAR-NOSED MOLE	SSC	**	S2?	G5
AMACC08020	CORYNORHINUS RAFINESQUII	RAFINESQUE'S BIG-EARED BAT	SSC	**	SH	G3
AMAFJ01010	ERETHIZON DORSATUM	COMMON PORCUPINE	SX	**	SX	G5
AMAJH01022	FELIS CONCOLOR COUGUAR	MOUNTAIN LION	SX	LE	SX	G5TH
AMAJH03010	FELIS LYNX	LYNX	SX	**	SX	G4G5
AMAFC02010	GEOMYS BURSARIUS	PLAINS POCKET GOPHER	SSC	**	S2	G5
AMAJF03010	GULO GULO	WOLVERINE	SX	**	SX	G4
AMAJF08010	LUTRA CANADENSIS	NORTHERN RIVER OTTER	SE	**	S?	G5
AMAJH03020	LYNX RUFUS	BOBCAT	SE	**	S1	G5
AMAJF01020	MARTES PENNANTI	FISHER	SX	**	SX	G4G5
AMAJF02020	MUSTELA NIVALIS	LEAST WEASEL	SSC	**	S2?	G5
AMACC01030	MYOTIS AUSTRORIPARIUS	SOUTHEASTERN MYOTIS	SE	**	S1	G3
AMACC01040	MYOTIS GRISESCENS	GRAY MYOTIS	SE	LE	S1	G2G3
AMACC01100	MYOTIS SODALIS	INDIANA OR SOCIAL MYOTIS	SE	LE	S1	G2
AMAFF08100	NEOTOMA MAGISTER	EASTERN WOODRAT	ST	**	S2	G3G4
AMACC06010	NYCTICEIUS HUMERALIS	EVENING BAT	SE	**	S1	G5
AMAFF21010	RATTUS RATTUS	BLACK RAT	SX	**	SX	G5
AMAFF02030	REITHRODONTOMYS MEGALOTIS	WESTERN HARVEST MOUSE	SSC	**	S2	G5
AMABA01180	SOREX FUMEUS	SMOKY SHREW	SSC	**	S2	G5
AMABA01250	SOREX HOYI	PYGMY SHREW	SSC	**	S2	G5
AMAFB05120	SPERMOPHILUS FRANKLINII	FRANKLIN'S GROUND SQUIRREL	ST	**	S2	G5
AMAJF05010	SPILOGALE PUTORIUS	EASTERN SPOTTED SKUNK	SX	**	SX	G5
AMAEB01080	SYLVILAGUS AQUATICUS	SWAMP RABBIT	SE	**	S1	G5
AMAJF04010	TAXIDEA TAXUS	AMERICAN BADGER	ST	**	S2	G5
AMAJB01010	URSUS AMERICANUS	BLACK BEAR	SX	T(S/A	SX	G5
** Bird						
ABNKC12040	ACCIPITER COOPERII	COOPER'S HAWK	WL	**	S3	G4
ABNKC12020	ACCIPITER STRIATUS	SHARP-SHINNED HAWK	SSC	**	S2	G5
ABNSB15020	AEGOLIUS ACADICUS	NORTHERN SAW-WHET OWL		**	S1S2	G5
ABPBX91050	AIMOPHILA AESTIVALIS	BACHMAN'S SPARROW	SE	**	S1	G3
ABPBXA0030	AMMODRAMUS HENSLOWII	HENSLOW'S SPARROW	ST	**	S2	G3G4
ABNJB10150	ANAS CLYPEATA	NORTHERN SHOVELER		**	S2?	G5
ABNJB10010	ANAS CRECCA	GREEN-WINGED TEAL		**	S2?	G5
ABNJB10040	ANAS RUBRIPES	AMERICAN BLACK DUCK		**	S2?	G4
ABNGA04040	ARDEA ALBA	GREAT EGRET	SE	**	S1	G5
ABNGA04010	ARDEA HERODIAS	GREAT BLUE HERON	SSC	**	S4	G5
ABNSB13040	ASIO FLAMMEUS	SHORT-EARED OWL	SE	**	S2	G5
ABNSB13010	ASIO OTUS	LONG-EARED OWL	WL	**	S2	G5
ABNJB11030	AYTHYA AMERICANA	REDHEAD		**	S1	G5
ABNJB11040	AYTHYA COLLARIS	RING-NECKED DUCK		**	S2	G5
ABNNF06010	BARTRAMIA LONGICAUDA	UPLAND SANDPIPER	SE	**	S1	G5
ABNGA01020	BOTAURUS LENTIGINOSUS	AMERICAN BITTERN	SE	**	S2	G4
ABNKC19030	BUTEO LINEATUS	RED-SHOULDERED HAWK	SSC	**	S3	G5
ABNKC19050	BUTEO PLATYPTERUS	BROAD-WINGED HAWK	SSC	**	S3	G5
ABPBY06030	CARDUELIS PINUS	PINE SISKIN		**	S2S3	G5
ABPBA01010	CERTHIA AMERICANA	BROWN CREEPER	WL	**	S3	G5
ABNNB03070	CHARADRIUS MELODUS	PIPING PLOVER	SE	LELT	S1	G3
ABNNM10020	CHLIDONIAS NIGER	BLACK TERN	SE	**	S1	G4
ABNKC11010	CIRCUS CYANEUS	NORTHERN HARRIER	SE	**	S2	G5
ABPBG10020	CISTOTHORUS PALUSTRIS	MARSH WREN	SE	**	S3	G5
ABPBG10010	CISTOTHORUS PLATENSIS	SEDGE WREN	ST	**	S3	G5
ABNKA01010	CORAGYPS ATRATUS	BLACK VULTURE	WL	**	S3	G5
ABPAV10110	CORVUS CORAX	COMMON RAVEN	SX	**	SX	G5
ABNJB02030	CYGNUS BUCCINATOR	TRUMPETER SWAN	SE	**	S?	G4
ABPBX03240	DENDROICA CERULEA	CERULEAN WARBLER	SSC	**	S2	G4
ABPBX03180	DENDROICA KIRTLANDII	KIRTLAND'S WARBLER	SE	LE	S1	G1
ABPBX03100	DENDROICA VIRENS	BLACK-THROATED GREEN WARBLER		**	S1S2	G5
ABNGA06040	EGRETTA CAERULEA	LITTLE BLUE HERON	WL	**	S1	G5
ABPAE33070	EMPIDONAX MINIMUS	LEAST FLYCATCHER	WL	**	S3	G5
ABPBXB5020	EUPHAGUS CYANOCEPHALUS	BREWER'S BLACKBIRD	SX	**	S?N	G5

STATE: SX-extirpated. SE-endangered. ST-threatened. SR-rare. SSC-special concern. WL-watch list. SG-significant. SRE-state reintroduced

FEDERAL: LE-endangered. LT-threatened. LELT-different listings for specific ranges of species. PE-proposed endangered. PT-proposed threatened. E/SA-appearance similar to LE species. **-not listed

January 22. 1997

ENDANGERED. THREATENED AND RARE VERTEBRATES AND INVERTEBRATES. INDIANA
INDIANA NATURAL HERITAGE DATA CENTER

ELCODE:...	SPECIES NAME:......................	COMMON NAME:....................	SPROT:	USESA:	SRANK:.	GRANK
ABNKD06070	FALCO PEREGRINUS	PEREGRINE FALCON	SE	E(S/A	S1	G4
ABNNF18010	GALLINAGO GALLINAGO	COMMON SNIPE		**	S2?	G5
ABNBA01030	GAVIA IMMER	COMMON LOON	SX	**	S?N	G5
ABNMK01010	GRUS CANADENSIS	SANDHILL CRANE	ST	**	S2	G5
ABNKC10010	HALIAEETUS LEUCOCEPHALUS	BALD EAGLE	SE	LTNL	S1	G4
ABPBX08010	HELMITHEROS VERMIVORUS	WORM-EATING WARBLER	SSC	**	S3	G5
ABNKC09010	ICTINIA MISSISSIPPIENSIS	MISSISSIPPI KITE	SSC	**	SA	G5
ABNGA02010	IXOBRYCHUS EXILIS	LEAST BITTERN	SE	**	S3	G5
ABPBR01030	LANIUS LUDOVICIANUS	LOGGERHEAD SHRIKE	SE	**	S1	G4G5
ABNJB20010	LOPHODYTES CUCULLATUS	HOODED MERGANSER		**	S2S3	G5
ABPBX05010	MNIOTILTA VARIA	BLACK-AND-WHITE WARBLER	SSC	**	S3	G5
ABNGA13010	NYCTANASSA VIOLACEA	YELLOW-CROWNED NIGHT-HERON	SE	**	S2	G5
ABNGA11010	NYCTICORAX NYCTICORAX	BLACK-CROWNED NIGHT-HERON	SE	**	S1	G5
ABNKC01010	PANDION HALIAETUS	OSPREY	SE	**	S1	G5
ABNFD01020	PHALACROCORAX AURITUS	DOUBLE-CRESTED CORMORANT	SX	**	S?N	G5
ABNNF20010	PHALAROPUS TRICOLOR	WILSON'S PHALAROPE	SX	**	S?N	G4
ABNME05020	RALLUS ELEGANS	KING RAIL	SE	**	S1	G4G5
ABNME05030	RALLUS LIMICOLA	VIRGINIA RAIL	SSC	**	S2	G5
ABPBX10020	SEIURUS NOVEBORACENSIS	NORTHERN WATERTHRUSH		**	S1	G5
ABNYF05010	SPHYRAPICUS VARIUS	YELLOW-BELLIED SAPSUCKER		**	S2?	G5
ABNNM08102	STERNA ANTILLARUM ATHALASSOS	INTERIOR LEAST TERN	SE	LENL	S1	G4T2Q
ABNNM08090	STERNA FORSTERI	FORSTER'S TERN	SX	**	S?N	G5
ABNNM08070	STERNA HIRUNDO	COMMON TERN	SX	**	S?N	G5
ABPBXB2030	STURNELLA NEGLECTA	WESTERN MEADOWLARK	SSC	**	S2	G5
ABPBG07010	THRYOMANES BEWICKII	BEWICK'S WREN	SE	**	S1	G4
ABNLC13010	TYMPANUCHUS CUPIDO	GREATER PRAIRIE-CHICKEN	SX	**	SX	G4
ABNSA01010	TYTO ALBA	BARN OWL	SE	**	S2	G5
ABPBX01030	VERMIVORA CHRYSOPTERA	GOLDEN-WINGED WARBLER	SE	**	S1	G4
ABPBX16030	WILSONIA CANADENSIS	CANADA WARBLER	SSC	**	S1S2	G5
ABPBX16010	WILSONIA CITRINA	HOODED WARBLER	SSC	**	S3	G5
ABPBXB3010	XANTHOCEPHALUS XANTHOCEPHALUS	YELLOW-HEADED BLACKBIRD	ST	**	S2	G5
** Reptile						
ARADE01022	AGKISTRODON PISCIVORUS LEUCOSTOMA	WESTERN COTTONMOUTH	ST	**	S1	G5T5
ARADB03012	CEMOPHORA COCCINEA COPEI	NORTHERN SCARLET SNAKE	ST	**	S1	G5T5
ARAAD02010	CLEMMYS GUTTATA	SPOTTED TURTLE	ST	**	S2	G5
ARADB06010	CLONOPHIS KIRTLANDII	KIRTLAND'S SNAKE	ST	**	S2	G2
ARADE02040	CROTALUS HORRIDUS	TIMBER RATTLESNAKE	ST	**	S2	G5
ARAAD04010	EMYDOIDEA BLANDINGII	BLANDING'S TURTLE	SE	**	S2	G4
ARADB14012	FARANCIA ABACURA REINWARDTII	WESTERN MUD SNAKE	SX	**	SX	G5T5
ARAAE01050	KINOSTERNON SUBRUBRUM	EASTERN MUD TURTLE	ST	**	S2	G5
ARAAB02010	MACROCLEMYS TEMMINCKII	ALLIGATOR SNAPPING TURTLE	SE	**	S1	G3G4
ARADB22023	NERODIA ERYTHROGASTER NEGLECTA	COPPERBELLY WATER SNAKE	ST	PT	S2	G5T2
ARADB23010	OPHEODRYS AESTIVUS	ROUGH GREEN SNAKE	SSC	**	S3	G5
ARADB23020	OPHEODRYS VERNALIS	SMOOTH GREEN SNAKE	ST	**	S2	G5
ARACB02010	OPHISAURUS ATTENUATUS	SLENDER GLASS LIZARD		**	S2	G5
ARAAD07024	PSEUDEMYS CONCINNA HIEROGLYPHICA	HIEROGLYPHIC RIVER COOTER	SE	**	S1	G5T4
ARADE03011	SISTRURUS CATENATUS CATENATUS	EASTERN MASSASAUGA	ST	**	S2	G3G4T3
ARADB35020	TANTILLA CORONATA	SOUTHEASTERN CROWNED SNAKE	ST	**	S1	G5
ARAAD08020	TERRAPENE ORNATA	ORNATE BOX TURTLE	SSC	**	S2	G5
ARADB36020	THAMNOPHIS BUTLERI	BUTLER'S GARTER SNAKE	ST	**	S1	G5
ARADB36090	THAMNOPHIS PROXIMUS	WESTERN RIBBON SNAKE	SSC	**	S3	G5
** Amphibian						
AAABC01010	ACRIS CREPITANS	NORTHERN CRICKET FROG		**	S?	G5
AAAAA01170	AMBYSTOMA BARBOURI	STREAMSIDE SALAMANDER	WL	**	S3	G4
AAAAA01060	AMBYSTOMA LATERALE	BLUE-SPOTTED SALAMANDER	SSC	**	S2	G5
AAAAD01010	ANEIDES AENEUS	GREEN SALAMANDER	SE	**	S?	G3G4
AAAAC01011	CRYPTOBRANCHUS ALLEGANIENSIS ALLEGANIENSIS	HELLBENDER	SE	**	S1	G4T4
AAAAD08010	HEMIDACTYLIUM SCUTATUM	FOUR-TOED SALAMANDER	ST	**	S2	G5
AAAAE01040	NECTURUS MACULOSUS	MUDPUPPY	SSC	**	S2	G5
AAAAD12150	PLETHODON RICHMONDI	RAVINE SALAMANDER	WL	**	S2	G5
AAAAD13022	PSEUDOTRITON RUBER RUBER	NORTHERN RED SALAMANDER	SE	**	S1	G5T5
AAABH01014	RANA AREOLATA CIRCULOSA	NORTHERN CRAWFISH FROG	ST	**	S2	G4T4
AAABH01040	RANA BLAIRI	PLAINS LEOPARD FROG	SSC	**	S2	G5

STATE: SX=extirpated. SE=endangered. ST=threatened. SR=rare. SSC=special concern. WL=watch
SG=significant. SRE=state reintroduced

FEDERAL: LE=endangered. LT=threatened. LELT=different listings for specific ranges of species. PE=prc
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ENDANGERED. THREATENED AND RARE VERTEBRATES AND INVERTEBRATES. INDIANA
INDIANA NATURAL HERITAGE DATA CENTER

ELCODE:...	SPECIES NAME:.....................	COMMON NAME:.....................	SPROT:	USESA:	SRANK:.	GRANK
AAABH01170	RANA PIPIENS	NORTHERN LEOPARD FROG	SSC	**	S2	G5
AAABF01041	SCAPHIOPUS HOLBROOKII HOLBROOKII	EASTERN SPADEFOOT	SSC	**	S2	G5T5
** Fish						
AFCAA01020	ACIPENSER FULVESCENS	LAKE STURGEON	SE	**	S1	G3
AFCFA01020	ALOSA ALABAMAE	ALABAMA SHAD	SX	**	SX	G4
AFCLA01020	AMBLYOPSIS SPELAEA	NORTHERN CAVEFISH	SE	**	S1	G3
AFCJC02030	CATOSTOMUS CATOSTOMUS	LONGNOSE SUCKER	WL	**	S2	G5
AFCJB05010	CLINOSTOMUS ELONGATUS	REDSIDE DACE	SE	**	S1	G5
AFCHA01020	COREGONUS ARTEDI	CISCO	SSC	**	S2	G5
AFCHA01050	COREGONUS HOYI	BLOATER	WL	**	S1	G3
AFCHA01060	COREGONUS JOHANNAE	DEEPWATER CISCO	WL	**	SX	GX
AFCHA01070	COREGONUS KIYI	KIYI	WL	**	S1	G3
AFCHA01100	COREGONUS NIGRIPINNIS	BLACKFIN CISCO	SX	**	SX	GXQ
AFCHA01120	COREGONUS REIGHARDI	SHORTNOSE CISCO	SX	**	SX	GH
AFCHA01140	COREGONUS ZENITHICUS	SHORTJAW CISCO	WL	**	S1	G2
AFCJB06010	COUESIUS PLUMBEUS	LAKE CHUB	WL	**	S2	G5
AFCQC01010	CRYSTALLARIA ASPRELLA	CRYSTAL DARTER	SX	**	SX	G3
AFCJC04010	CYCLEPTUS ELONGATUS	BLUE SUCKER	SSC	**	S2	G3
AFCQC02100	ETHEOSTOMA CAMURUM	BLUEBREAST DARTER	SE	**	S1	G4
AFCQC02B60	ETHEOSTOMA CLARUM	WESTERN SAND DARTER		**	S3	G3
AFCQC02310	ETHEOSTOMA HISTRIO	HARLEQUIN DARTER	SE	**	S1	G5
AFCQC02420	ETHEOSTOMA MACULATUM	SPOTTED DARTER	SE	**	S1	G2
AFCQC02B80	ETHEOSTOMA PELLUCIDUM	EASTERN SAND DARTER	SSC	**	S2	G3
AFCQC02730	ETHEOSTOMA SQUAMICEPS	SPOTTAIL DARTER	SE	**	S1	G5
AFCQC02800	ETHEOSTOMA TIPPECANOE	TIPPECANOE DARTER	SE	**	S1	G3
AFCQC02830	ETHEOSTOMA VARIATUM	VARIEGATE DARTER	SE	**	S1	G5
AFCNB04020	FUNDULUS CATENATUS	NORTHERN STUDFISH	SSC	**	S2	G5
AFCJB16030	HYBOGNATHUS HAYI	CYPRESS MINNOW	WL	**	S2	G5
AFCJB28880	HYBOPSIS AMBLOPS	BIGEYE CHUB	WL	**	S2	G5
AFCJB28050	HYBOPSIS AMNIS	PALLID SHINER	WL	**	S2	G4
AFBAA01010	ICHTHYOMYZON BDELLIUM	OHIO LAMPREY	WL	**	S2	G3G4
AFCJC07030	ICTIOBUS NIGER	BLACK BUFFALO	WL	**	S2	G5
AFBAA02010	LAMPETRA AEPYPTERA	LEAST BROOK LAMPREY	WL	**	S2	G5
AFCBA01050	LEPISOSTEUS SPATULA	ALLIGATOR GAR	WL	**	S2	G5
AFCQB11110	LEPOMIS SYMMETRICUS	BANTAM SUNFISH	SX	**	S1	G5
AFCJC10040	MOXOSTOMA CARINATUM	RIVER REDHORSE	SSC	**	S3	G4
AFCJC10170	MOXOSTOMA VALENCIENNESI	GREATER REDHORSE	SSC	**	S2	G3
AFCJB28080	NOTROPIS ANOGENUS	PUGNOSE SHINER	WL	**	S1	G3
AFCJB28410	NOTROPIS DORSALIS	BIGMOUTH SHINER	WL	**	S2	G5
AFCJB28530	NOTROPIS HETEROLEPIS	BLACKNOSE SHINER	WL	**	S2	G5
AFCJB28950	NOTROPIS TEXANUS	WEED SHINER	WL	**	S2	G5
AFCKA02180	NOTURUS NOCTURNUS	FRECKLED MADTOM	WL	**	S1	G5
AFCKA02220	NOTURUS STIGMOSUS	NORTHERN MADTOM	WL	**	S1	G4
AFCJB55010	OPSOPOEODUS EMILIAE	PUGNOSE MINNOW	WL	**	S2	G5
AFCQC04060	PERCINA COPELANDI	CHANNEL DARTER	WL	**	S2	G4
AFCQC04090	PERCINA EVIDES	GILT DARTER	SE	**	S1	G4
AFCQC04300	PERCINA URANIDEA	STARGAZING DARTER	SX	**	SX	G3
AFCLC01010	PERCOPSIS OMISCOMAYCUS	TROUT-PERCH	WL	**	S2	G5
AFCAB01010	POLYODON SPATHULA	PADDLEFISH	WL	**	S3	G4
AFCHA05050	SALVELINUS NAMAYCUSH	LAKE TROUT	WL	**	S2	G5
AFCLA04010	TYPHLICHTHYS SUBTERRANEUS	SOUTHERN CAVEFISH	SE	**	S1	G3
** Crustacean						
ICCOP08011	BRYOCAMPTUS MORRISONI MORRISONI	MORRISON'S CAVE COPEPOD	SE	**	S1	G?T?
ICMAL01190	CAECIDOTEA JORDANI	JORDAN CAVE ISOPOD	SE	**	S2	G1
ICMAL01340	CAECIDOTEA ROTUNDA	NORTHEASTERN CAVE ISOPOD	SE	**	S1	G2
ICMAL01470	CAECIDOTEA TERESAE	GROUNDWATER ISOPOD	SE	**	S1	G?
ICMAL07110	CAMBARUS ORTMANNI	BURROWING CRAYFISH		**	S2	G2G3
ICMAL07120	CAMBARUS ROBUSTUS	A CRAYFISH		**	S2	G5
ICMAL06090	CRANGONYX PACKARDI	PACKARD'S CAVE AMPHIPOD	SR	**	S2	G2
ICMAL06X10	CRANGONYX SP 1	UNDESCRIBED CAVE AMPHIPOD	SR	**	S2	G2
ICCOP02020	DIACYCLOPS JEANNELI	JEANNEL'S CAVE COPEPOD	SE	**	S1	G1
ICMAL10010	GAMMARUS BOUSFIELDI	SPRING AMPHIPOD	SE	**	S1	G1
ICBRA08010	LYNCEUS BRACHYURUS	CLAM SHRIMP	WL	**	S1?	G?

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ICCOP09010	MEGACYCLOPS DONNALDSONI	DONALDSONS CAVE COPEPOD	SE	**	S1	G1
ICMAL11100	ORCONECTES INDIANENSIS	INDIANA CRAYFISH	SSC	**	S2	G2G3
ICMAL11031	ORCONECTES INERMIS INERMIS	A TROGLOBITIC CRAYFISH		**	S3	G5T4
ICMAL11032	ORCONECTES INERMIS TESTII	TROGLOBITIC CRAYFISH	ST	**	S2	G5T3
ICMAL11610	ORCONECTES PUTNAMI	A CRAYFISH		**	S2	G3
ICMAL11150	ORCONECTES SLOANII	CRAYFISH		**	S1S2	G2
ICMAL14440	PROCAMBARUS CLARKII	RED SWAMP CRAYFISH		**	S?	G5
ICMAL14310	PROCAMBARUS GRACILIS	PRAIRIE CRAYFISH		**	S1S2	G5
ICOST11010	PSEUDOCANDONA JEANNELI	JEANNEL'S CAVE OSTRACOD	SE	**	S1	G?
ICOST11020	PSEUDOCANDONA MARENGOENSIS	MARENGO CAVE OSTRACOD	SE	**	S1	G?
ICMAL05300	STYGOBROMUS MACKINI	SOUTHWESTERN VIRGINIA CAVE AMPHIPOD	SE	**	S1	G3G4
ICMAL05X20	STYGOBROMUS SP 2	UNDESCRIBED AMPHIPOD	SE	**	S1	G1
** Mussel						
IMBIV02110	ALASMIDONTA VIRIDIS	SLIPPERSHELL MUSSEL	WL	**	S2	G4
IMBIV06010	ARCIDENS CONFRAGOSUS	ROCK-POCKETBOOK	WL	**	S2	G3
IMBIV08010	CUMBERLANDIA MONODONTA	SPECTACLECASE	SX	**	SX	G2G3
IMBIV10020	CYPROGENIA STEGARIA	EASTERN FANSHELL PEARLYMUSSEL	SE	LE	S1	G1
IMBIV16050	EPIOBLASMA FLEXUOSA	LEAFSHELL	SX	**	SX	GX
IMBIV16111	EPIOBLASMA OBLIQUATA OBLIQUATA	PURPLE CATSPAW	SX	LE	SX	G1T?
IMBIV16112	EPIOBLASMA OBLIQUATA PEROBLIQUA	WHITE CAT'S PAW PEARLYMUSSEL	SE	LE	S1	G1T1
IMBIV16140	EPIOBLASMA PERSONATA	ROUND COMBSHELL	SX	**	SX	GX
IMBIV16150	EPIOBLASMA PROPINQUA	TENNESSEE RIFFLESHELL	SX	**	SX	GX
IMBIV16160	EPIOBLASMA SAMPSONII	WABASH RIFFLESHELL	SX	**	SX	GX
IMBIV16184	EPIOBLASMA TORULOSA RANGIANA	NORTHERN RIFFLESHELL	SE	LE	S1	G2T2
IMBIV16183	EPIOBLASMA TORULOSA TORULOSA	TUBERCLED BLOSSOM	SE	LE	S1	G2TX
IMBIV16190	EPIOBLASMA TRIQUETRA	SNUFFBOX	SE	**	S1	G3
IMBIV17120	FUSCONAIA SUBROTUNDA	LONG-SOLID	SE	**	S1	G4
IMBIV20010	HEMISTENA LATA	CRACKING PEARLYMUSSEL	SX	LE	SX	G1
IMBIV21110	LAMPSILIS ABRUPTA	PINK MUCKET	SE	LE	S1	G2
IMBIV21070	LAMPSILIS FASCIOLA	WAVY-RAYED LAMPMUSSEL	SSC	**	S2	G4
IMBIV21130	LAMPSILIS OVATA	POCKETBOOK	WL	**	S2	G5
IMBIV21240	LAMPSILIS TERES	YELLOW SANDSHELL	WL	**	S2	G5
IMBIV24020	LEPTODEA LEPTODON	SCALESHELL	SX	**	SX	G2G3
IMBIV26020	LIGUMIA RECTA	BLACK SANDSHELL	WL	**	S2	G5
IMBIV31030	OBOVARIA RETUSA	RING PINK	SX	LE	SX	G1
IMBIV31050	OBOVARIA SUBROTUNDA	ROUND HICKORYNUT	SSC	**	S2	G3
IMBIV34010	PLETHOBASUS CICATRICOSUS	WHITE WARTYBACK	SE	LE	S1	G1
IMBIV34020	PLETHOBASUS COOPERIANUS	ORANGE-FOOT PIMPLEBACK	SE	LE	S1	G1
IMBIV34030	PLETHOBASUS CYPHYUS	SHEEPNOSE	SE	**	S1	G3
IMBIV35060	PLEUROBEMA CLAVA	CLUBSHELL	SE	LE	S1	G1
IMBIV35070	PLEUROBEMA COCCINEUM	ROUND PIGTOE		**	S3	G3G4
IMBIV35090	PLEUROBEMA CORDATUM	OHIO PIGTOE	SSC	**	S2	G3
IMBIV35240	PLEUROBEMA PLENUM	ROUGH PIGTOE	SE	LE	S1	G1
IMBIV35250	PLEUROBEMA PYRAMIDATUM	PYRAMID PIGTOE	SE	**	S1	G2G3
IMBIV37030	POTAMILUS CAPAX	FAT POCKETBOOK	SE	LE	S1	G1
IMBIV38010	PTYCHOBRANCHUS FASCIOLARIS	KIDNEYSHELL	SSC	**	S2	G4
IMBIV39041	QUADRULA CYLINDRICA CYLINDRICA	RABBITSFOOT	SE	**	S1	G4T2T3
IMBIV39050	QUADRULA FRAGOSA	WINGED MAPLELEAF	SX	LE	SX	G1
IMBIV39080	QUADRULA METANEVRA	MONKEYFACE		**	S3	G3
IMBIV39090	QUADRULA NODULATA	WARTYBACK		**	S3	G3G4
IMBIV41010	SIMPSONAIAS AMBIGUA	SALAMANDER MUSSEL	SSC	**	S2	G2
IMBIV43030	TOXOLASMA LIVIDUM	PURPLE LILLIPUT	SSC	**	S2	G1G2Q
IMBIV43050	TOXOLASMA PARVUM	LILLIPUT	WL	**	S2	G4
IMBIVA4010	VENUSTACONCHA ELLIPSIFORMIS	ELLIPSE	SSC	**	S2	G3
IMBIV47050	VILLOSA FABALIS	RAYED BEAN	SSC	**	S1	G2
IMBIV47070	VILLOSA LIENOSA	LITTLE SPECTACLECASE	SSC	**	S2	G5
** Gastropod						
IMGASJ8010	ANTROSELATUS SPIRALIS	SHAGGY CAVE SNAIL	ST	**	S2	G2G3
IMGASE6040	CAMPELOMA DECISUM	POINTED CAMPELOMA	SSC	**	S2	G5
IMGASK2601	ELIMIA SEMICARINATA INDIANENSIS	INDIANA RIVER SNAIL	WL	**	S1	G?T?
IMGASG5020	FONTIGENS CRYPTICA	HIDDEN SPRINGS SNAIL	SE	**	S1	G1
IMGASK6010	LITHASIA ARMIGERA	ARMORED ROCKSNAIL	WL	**	S?	G?
IMGASL2020	LYMNAEA STAGNALIS	SWAMP LYMNAEA	SSC	**	S2	G5
IMGASA1280	TRIODOPSIS OBSTRICTA	SHARP WEDGE	SE	**	S1	G?

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** Lepidoptera: Butterflies. Skippers. Moths						
IILEP80120	AMBLYSCIRTES AESCULAPIUS			**	S1	G4
IILEP80200	AMBLYSCIRTES BELLI	BELL'S ROADSIDE SKIPPER		**	S1S2	G4
IILEP80080	AMBLYSCIRTES HEGON	SALT-AND-PEPPER SKIPPER	WL	**	S1S3	G5
IILEPA2014	ARTOGEIA NAPI OLERACEA	VEINED WHITE	SE	**	S1	G5T4
IILEPA2020	ARTOGEIA VIRGINIENSIS	WEST VIRGINIA WHITE	SR	**	S3	G4
IILEP79010	ATRYTONOPSIS HIANNA	DUSTED SKIPPER	ST	**	S2S3	G4G5
IILEP14010	AUTOCHTON CELLUS	GOLDEN-BANDED SKIPPER	WL	**	S1S2	G4
IILEYC4040	BELLURA DENSA	NOCTUID MOTH		**	S?	G5
IILEPJ7031	BOLORIA SELENE MYRINA	SILVER-BORDERED FRITILLARY		**	S2S3	G5T5
IILEPJ7036	BOLORIA SELENE NEBRASKENSIS	NEBRASKA FRITILLARY		**	S1?	
IILEPH2020	CALEPHELIS BOREALIS	NORTHERN METALMARK		**	S3	G3G4
IILEPH2060	CALEPHELIS MUTICA	SWAMP METALMARK	SR	**	S2S3	G4
IILEPE1010	CALYCOPIS CECROPS	RED-BANDED HAIRSTREAK		**	S2S3	G5
IILEY89A40	CATOCALA DULCIOLA			**	S?	G3
IILEY89350	CATOCALA MARMORATA	MARBLED UNDERWING MOTH		**	S1	G4
IILEPG0020	CELASTRINA EBENINA	SOOTY AZURE	WL	**	S2	G4
IILEPG0030	CELASTRINA NEGLECTAMAJOR	APPALACHIAN BLUE		**	S1S2	G4
IILEPJ9150	CHLOSYNE HARRISII	HARRIS' CHECKERSPOT	SR	**	S2	G4
IILEPN1040	CYLLOPSIS GEMMA	GEMMED SATYR	SR	**	S2	G5
IILEPM9030	ENODIA CREOLA	CREOLE PEARLY EYE	SX	**	SU	G4?
IILEY80010	EOSPHOROPTERYX THYATYROIDES	PINKPATCHED LOOPER MOTH	ST	**	S2	G4G5
IILEP37140	ERYNNIS LUCILIUS	COLUMBINE DUSKYWING		**	S1?	G4
IILEP37100	ERYNNIS MARTIALIS	MOTTLED DUSKYWING	ST	**	S3	G4
IILEP37171	ERYNNIS PERSIUS PERSIUS	PERSIUS DUSKYWING	SE	**	S1S2	G4T2T3
IILEPA5040	EUCHLOE OLYMPIA	OLYMPIA MARBLEWING	ST	**	S2	G4
IILEPK4060	EUPHYDRYAS PHAETON	BALTIMORE		**	S2S4	G4
IILEP77090	EUPHYES BIMACULA	TWO-SPOTTED SKIPPER	SR	**	S2	G4
IILEP77050	EUPHYES DUKESI	SCARCE SWAMP SKIPPER	SR	**	S2	G3
IILEPE9010	EURISTRYMON ONTARIO	NORTHERN HAIRSTREAK	WL	**	S2S4	G4
IILEPG4022	GLAUCOPSYCHE LYGDAMUS COUPERI	SILVERY BLUE	SE	**	S1	G5T4
IILEW0MX30	HEMILEUCA SP 3	MIDWESTERN FEN BUCKMOTH		**	S1?	G3G4
IILEPN2020	HERMEUPTYCHIA SOSYBIUS	CAROLINA SATYR		**	S1S2	G5Q
IILEP65060	HESPERIA LEONARDUS	LEONARDUS SKIPPER	SR	**	S2	G4
IILEP65100	HESPERIA METEA	COBWEB SKIPPER	ST	**	S2S3	G4G5
IILEP65050	HESPERIA OTTOE	OTTOE SKIPPER	SE	**	S1	G3?
IILEP65160	HESPERIA SASSACUS	INDIAN SKIPPER	SR	**	S3	G5
IILEY04010	HYPERAESCHRA TORTUOSA	A PROMINENT MOTH	ST	**	S2	G?
IILEPE7051	INCISALIA HENRICI TURNERI	HENRY'S ELFIN		**	S2S4	G5T4T5
IILEPE7040	INCISALIA IRUS	FROSTED ELFIN	SR	**	S2	G4
IILEPE7030	INCISALIA POLIA	HOARY ELFIN	SR	**	S1?	G5
IILEPG5021	LYCAEIDES MELISSA SAMUELIS	KARNER BLUE BUTTERFLY	SE	LE	S1	G5T2
IILEPC1121	LYCAENA DORCAS DORCAS	DORCAS COPPER		**	S2	G4TU
IILEPC1110	LYCAENA EPIXANTHE	BOG COPPER	SX	**	SX	G4G5
IILEPC1130	LYCAENA HELLOIDES	PURPLISH COPPER		**	S2S4	G5
IILEPC1040	LYCAENA XANTHOIDES	GREAT COPPER	WL	**	S?	G5
IILEU2E040	LYTROSIS PERMAGNARIA	A LYTROSIS MOTH	ST	**	S2	GU
IILEU3C110	METARRANTHIS APICIARIA	BARRENS METARRANTHIS MOTH	WL	**	SH	GU
IILEPE4091	MITOURA GRYNEA GRYNEA	OLIVE HAIRSTREAK		**	S2S4	G5T5
IILEPN3021	NEONYMPHA MITCHELLII MITCHELLII	MITCHELL'S SATYR	SE	LE	S1	G2T2
IILEP57010	OARISMA POWESHEIK	POWESHIEK SKIPPER	SX	**	SH	G2G3
IILEYC0310	PAPAIPEMA ERYNGII	RATTLESNAKE-MASTER BORER MOTH	SX	**	SX	G1
IILEYC0150	PAPAIPEMA LEUCOSTIGMA	COLUMBINE BORER	WL	**	S?	G4
IILEPF1010	PARRHASIUS M-ALBUM	WHITE M HAIRSTREAK		**	S1S3	G5
IILEP73071	POANES VIATOR VIATOR	BROAD-WINGED SKIPPER	SR	**	S2	G5T4
IILEPK5100	POLYGONIA PROGNE	GRAY COMMA		**	S2S4	G5
IILEP71010	PROBLEMA BYSSUS	BUNCHGRASS SKIPPER	SR	**	S2	G3G4
IILEYFF030	PYREFERRA CEROMATICA	ANNOINTED SALLOW MOTH	SR	**	S2	GU
IILEPN0022	SATYRODES APPALACHIA APPALACHIA	APPALACHIAN EYED BROWN	SE	**	S1	G5T5
IILEPN0012	SATYRODES EURYDICE FUMOSA	SMOKEY-EYED BROWN		**	S1S2	G5T3T4
IILEYMP890	SCHINIA GLORIOSA	GLORIUS FLOWER MOTH	WL	**	SU	G4
IILEYMP130	SCHINIA INDIANA	PHLOX MOTH	SE	**	S1	GU
IILEPJ6110	SPEYERIA ATLANTIS	ATLANTIS FRITILLARY		**	S1?	G5
IILEPJ6010	SPEYERIA DIANA	DIANA		**	SX	G3
IILEPJ6040	SPEYERIA IDALIA	REGAL FRITILLARY	SE	**	S1	G3
IILEP16050	THORYBES CONFUSIS	EASTERN CLOUDYWING		**	S1?	G4

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** Odonata: Dragonflies. Damselflies						
IIODO14020	AESHNA CANADENSIS	CANADA DARNER		**	S1	G5
IIODO14030	AESHNA CLEPSYDRA	MOTTLED DARNER		**	S1	G4
IIODO14110	AESHNA MUTATA	SPATTERDOCK DARNER		**	S1S2	G3G4
IIODO14180	AESHNA TUBERCULIFERA	BLACK-TIPPED DARNER		**	S2	G4
IIODO15030	ANAX LONGIPES	COMET DARNER		**	S2	G5
IIODO75010	ARCHILESTES GRANDIS	GREAT SPREADWING	SR	**	S3	G5
IIODO81040	ARIGOMPHUS CORNUTUS	HORNED CLUBTAIL		**	S1	G4
IIODO81050	ARIGOMPHUS FURCIFER	LILYPAD CLUBTAIL		**	S1	G5
IIODO81010	ARIGOMPHUS LENTULUS	STILLWATER CLUBTAIL		**	S1	G5
IIODO65010	CALOPTERYX AEQUABILIS	RIVER JEWELWING		**	S1	G5
IIODO65020	CALOPTERYX ANGUSTIPENNIS	APPALACHIAN JEWELWING		**	S1	G4
IIODO37090	CELITHEMIS VERNA	DOUBLE-RINGED PENNANT		**	S1	G5
IIODO78010	CHROMAGRION CONDITUM	AURORA DAMSEL		**	S2S3	G5
IIODO03090	CORDULEGASTER BILINEATA	BROWN SPIKETAIL		**	S1	G5
IIODO03020	CORDULEGASTER DIASTATOPS	DELTA-SPOTTED SPIKETAIL		**	S1	G5
IIODO03040	CORDULEGASTER ERRONEA	TIGER SPIKETAIL		**	S1	G4
IIODO03060	CORDULEGASTER MACULATA	TWIN-SPOTTED SPIKETAIL		**	S2S3	G5
IIODO03070	CORDULEGASTER OBLIQUA	ARROWHEAD SPIKETAIL		**	S2S3	G4
IIODO28020	DOROCORDULIA LIBERA	RACKET-TAILED EMERALD		**	S1	G5
IIODO71010	ENALLAGMA BOREALE	BOREAL BLUET		**	S1S2	G5
IIODO71150	ENALLAGMA CYATHIGERUM	NORTHERN BLUET		**	S1S2	G5
IIODO71160	ENALLAGMA DIVAGANS	TURQUOISE BLUET		**	S3	G5
IIODO06040	ERPETOGOMPHUS DESIGNATUS	EASTERN RINGTAIL		**	S2	G5
IIODO08090	GOMPHUS CRASSUS	HANDSOME CLUBTAIL		**	S2	G3G4
IIODO08110	GOMPHUS EXTERNUS	PLAINS CLUBTAIL		**	S2S3	G5
IIODO08140	GOMPHUS LINEATIFRONS	SPLENDID CLUBTAIL		**	S2	G4
IIODO08380	GOMPHUS QUADRICOLOR	RAPIDS CLUBTAIL		**	S2	G3G4
IIODO08400	GOMPHUS SPICATUS	DUSKY CLUBTAIL		**	S2	G5
IIODO08210	GOMPHUS VENTRICOSUS	SKILLET CLUBTAIL		**	S1S2	G3
IIODO08460	GOMPHUS VIRIDIFRONS	GREEN-FACED CLUBTAIL		**	S1S2	G3
IIODO09010	HAGENIUS BREVISTYLUS	DRAGONHUNTER		**	S2S3	G5
IIODO66020	HETAERINA TITIA	SMOKY RUBYSPOT		**	S2S3	G5
IIODO72020	ISCHNURA KELLICOTTI	LILYPAD FORKTAIL		**	S2	G5
IIODO72040	ISCHNURA PROGNATA	FURTIVE FORKTAIL		**	S1	G4
IIODO45230	LADONA JULIA	CHALK-FRONTED SKIMMER		**	S2S3	G5
IIODO44020	LEUCORRHINIA FRIGIDA	FROSTED WHITEFACE		**	S2	G5
IIODO26080	MACROMIA PACIFICA	GILDED RIVER CRUISER		**	S1S2	G4
IIODO26110	MACROMIA WABASHENSIS	WABASH BELTED SKIMMER DRAGONFLY		**	S1	G1G3Q
IIODO50010	NANNOTHEMIS BELLA	DWARF SKIMMER		**	S1	G4
IIODO74030	NEHALENNIA GRACILIS	SPHAGNUM SPRITE		**	S1	G5
IIODO74020	NEHALENNIA IRENE	SEDGE SPRITE		**	S2S3	G5
IIODO31040	NEUROCORDULIA OBSOLETA	UMBER SHADOWFLY		**	S1S2	G4
IIODO31070	NEUROCORDULIA YAMASKANENSIS	STYGIAN SHADOWFLY		**	S1S2	G5
IIODO12150	OPHIOGOMPHUS RUPINSULENSIS	RUSTY SNAKETAIL		**	S2S3	G5
IIODO32060	SOMATOCHLORA ENSIGERA	LEMON-FACED EMERALD		**	S1	G4
IIODO32110	SOMATOCHLORA HINEANA	OHIO EMERALD DRAGONFLY	SX	LE	SX	G2
IIODO32150	SOMATOCHLORA LINEARIS	MOCHA EMERALD		**	S2S3	G5
IIODO32230	SOMATOCHLORA TENEBROSA	CLAMP-TIPPED EMERALD		**	S2S3	G5
IIODO80010	STYLURUS AMNICOLA	RIVERINE CLUBTAIL		**	S1S2	G3G4
IIODO80040	STYLURUS LAURAE	LAURA'S CLUBTAIL		**	S1	G3G4
IIODO80050	STYLURUS NOTATUS	ELUSIVE CLUBTAIL DRAGONFLY		**	S1	G3G4
IIODO80090	STYLURUS SCUDDERI	ZEBRA CLUBTAIL		**	S1	G3
IIODO61050	SYMPETRUM DANAE	BLACK MEADOWFLY		**	S1	G5
IIODO61130	SYMPETRUM SEMICINCTUM	BAND-WINGED MEADOWFLY		**	S2S3	G5
IIODO01010	TACHOPTERYX THOREYI	GRAY PETALTAIL		**	S2S3	G4
IIODO29080	TETRAGONEURIA SPINIGERA	SPINY BASKETTAIL		**	S1	G5
** Coleoptera: Beetles						
IICOLA8060	BATRISODES KREKELERI	CAVE BEETLE	SE	**	S1	G1
IICOL02060	CICINDELA MARGINIPENNIS	COBBLESTONE TIGER BEETLE	SE	**	S1	G2G3
IICOL02230	CICINDELA PATRUELA	A TIGER BEETLE		**	S3	G3
IICOL03010	DRYOBIUS SEXNOTATUS	SIX-BANDED LONGHORN BEETLE	ST	**	S?	G?
IICOL86020	DYNASTES TITYUS	UNICORN BEETLE	SR	**	S2	G?
IICOL72010	LISSOBIOPS SERPENTINUS	A ROVE BEETLE	SE	**	S1	G?
IICOL42010	NICROPHORUS AMERICANUS	AMERICAN BURYING BEETLE	SX	LE	SH	G1

STATE: SX=extirpated. SE=endangered. ST=threatened. SR=rare. SSC=special concern. WL=watch
SG=significant. SRE=state reintroduced

FEDERAL: LE=endangered. LT=threatened. LELT=different listings for specific ranges of species. PE=proposed endangered. PT=proposed threatened. E/SA=appearance similar to LE species. **=not listed

ENDANGERED. THREATENED AND RARE VERTEBRATES AND INVERTEBRATES. INDIANA
INDIANA NATURAL HERITAGE DATA CENTER

ELCODE:...	SPECIES NAME:......................	COMMON NAME:.....................	SPROT:	USESA:	SRANK:.	GRANK
IICOL5S020	OCHTHEBIUS PUTNAMENSIS	INDIANA OCHTHEBIUS MINUTE MOSS BEETLE	SR	**	S2	GH
IICOL4EAE0	PSEUDANOPHTHALMUS BARRI	CAVE BEETLE	SE	**	S1	G1
IICOL4EAF0	PSEUDANOPHTHALMUS CHTHONIUS	CAVE BEETLE	SE	**	S1	G1
IICOL4EA90	PSEUDANOPHTHALMUS EMERSONI	CAVE BEETLE	SE	**	S1	G1
IICOL4EA80	PSEUDANOPHTHALMUS EREMITA	CAVE BEETLE	SE	**	S1	G1
IICOL4EAB3	PSEUDANOPHTHALMUS JEANNELI	CAVE BEETLE	SE	**	S1	G?
IICOL4EAA0	PSEUDANOPHTHALMUS LEONAE	CAVE BEETLE	SE	**	S1	G1
IICOL4EAD0	PSEUDANOPHTHALMUS SHILOHENSIS	CAVE BEETLE	SE	**	S1	G1
IICOL4EAD2	PSEUDANOPHTHALMUS SHILOHENSIS BOONENSIS	CAVE BEETLE	SE	**	S1	G?
IICOL4EAD1	PSEUDANOPHTHALMUS SHILOHENSIS MAYFIELDENSIS	CAVE BEETLE	SE	**	S1	G?
IICOL4EAB0	PSEUDANOPHTHALMUS TENUIS	CAVE BEETLE	ST	**	S2	G2
IICOL4EAB2	PSEUDANOPHTHALMUS TENUIS BLATCHLEYI	CAVE BEETLE	SE	**	S1	G?
IICOL4EAB1	PSEUDANOPHTHALMUS TENUIS MORRISONI	CAVE BEETLE	SE	**	S1	G?
IICOL4EAC0	PSEUDANOPHTHALMUS YOUNGI	CAVE BEETLE	SE	**	S1	G1
IICOL4EAC1	PSEUDANOPHTHALMUS YOUNGI DONALDSONI	CAVE BEETLE	SE	**	S1	G?
IICOL5F020	STENELMIS DOUGLASENSIS	DOUGLAS STENELMIS RIFFLE BEETLE	WL	**	S?	G1G3
**** Ephemeroptera: Mayflies**						
IIEPH19010	ANEPEORUS SIMPLEX	A FLAT-HEADED MAYFLY	SE	**	S1	G3G5
IIEPH43010	EPEORUS NAMATUS	A MAYFLY	SE	**	S1	G?
IIEPH11010	EPHEMERELLA ARGO	ARGO EPHEMERELLAN MAYFLY	SE	**	S?	G1G3
IIEPH03030	HOMOEONEURIA AMMOPHILA	A SAND-FILTERING MAYFLY	SE	**	S1	G4G5
IIEPH22010	PARACLOEODES MINUTUS	A SMALL MINNOW MAYFLY	SR	**	S2	G?
IIEPH13010	PENTAGENIA ROBUSTA	ROBUST PENTAGENIA BURROWING MAYFLY	SX	**	SX	GH
IIEPH13020	PENTAGENIA VITTIGERA	A PENTAGENIAN BURROWING MAYFLY	ST	**	S2	G4G5
IIEPH04020	PSEUDIRON CENTRALIS	A MAYFLY	SE	**	S1	G?
IIEPH44010	RAPTOHEPTAGENIA CRUENTATA	A FLATHEADED MAYFLY	SE	**	S1	G?
IIEPH21020	SIPHLOPLECTON BASALE	A SAND MINNOW MAYFLY	SE	**	S2	G?
IIEPH21010	SIPHLOPLECTON INTERLINEATUM	A SAND MINNOW MAYFLY		**	S1	G?
IIEPH20010	SPINADIS WALLACEI	WALLACE'S DEEPWATER MAYFLY	SE	**	S?	G?
IIEPH06010	TORTOPUS PRIMUS	A MAYFLY	ST	**	S2	G?
**** Trichoptera: Caddisflies**						
IITRI33060	AGAPETUS GELBAE	AN AGAPETUS CADDISFLY		**	S2	G?
IITRI33050	AGAPETUS ILLINI	AN AGAPETUS CADDISFLY		**	S2	G?
IITRI2A060	CERACLEA SP 1	A SPONGE-FEEDING CADDISFLY	ST	**	S2	G?
IITRI23020	DIPLECTRONA METAQUI	A DIPLECTRONAN CADDISFLY		**	S2	G?
IITRI95010	GOERA STYLATA	A NORTHERN CASEMAKER CADDISFLY	SE	**	S1	G?
IITRI24020	HOMOPLECTRA DORINGA	A HOMOPLECTRAN CADDISFLY	SE	**	S1	G?
IITRI85010	NECTOPSYCHE PAVIDA	A LONGHORNED CASEMAKER CADDISFLY	SR	**	S2	G?
IITRI90010	PYCNOPSYCHE ROSSI	A NORTHERN CASEMAKER CADDISFLY	SE	**	S1	G?
IITRI86010	SETODES OLIGIUS	A CADDISFLY	SE	**	S1	G?
**** Homoptera: Leafhoppers**						
IIHOM18010	MESAMIA STRAMINEA	HELIANTHUS LEAFHOPPER	WL	**	S?	G?
IIHOM17010	PRAIRIANA KANSANA	A LEAFHOPPER	WL	**	S?	G?
**** Neuroptera: Lacewings**						
IINEU15010	CLIMACIA SP 1	A SPONGILLA FLY	ST	**	S2	G?
IINEU07020	LOMAMYIA BANKSI	A BEADED LACEWING		**	S2	G?
IINEU07010	LOMAMYIA FLAVICORNIS	A BEADED LACEWING		**	S2	G?
IINEU09010	NALLACHIUS AMERICANUS	A PLEASING LACEWING		**	S2	G?
IINEU08010	POLYSTOECHOTES PUNCTATUS	A GIANT LACEWING	SX	**	SX	G?
IINEU11020	SISYRA SP 1	A SPONGILLA FLY	ST	**	S2	G?
**** Mecoptera**						
IIMEC08150	BOREUS SP 1			**	S2	G1
IIMEC01010	MEROPE TUBER	EARWIG SCORPIONFLY	SE	**	S1	G3G5
**** Other Type**						
ILARA29050	APOCTHONIUS INDIANENSIS	CAVE PSEUDOSCORPION	SE	**	S1	G?
IICLL04070	ARRHOPALITES BIMUS	SPRINGTAIL	SE	**	S1	G?

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FEDERAL: LE-endangered. LT-threatened. LELT-different listings for specific ranges of species. PE-proposed endangered. PT-proposed threatened. E/SA-appearance similar to LE species. **-not listed

ENDANGERED. THREATENED AND RARE VERTEBRATES AND INVERTEBRATES. INDIANA
INDIANA NATURAL HERITAGE DATA CENTER

ELCODE:...	SPECIES NAME:.....................	COMMON NAME:.....................	SPROT:	USESA:	SRANK:.	GRANK
ILARA92010	CHTHONIUS VIRGINICUS	PSEUDOSCORPION	SE	**	S1	G?
ITUNI04090	CONOTYLA BOLLMANI	MILLIPEDE	SR	**	S2	G?
ILARA48030	HESPEROCHERNES MIRABILIS	CAVE PSEUDOSCORPION	SE	**	S1	G3G4
ILARA21010	PORHOMMA CAVERNICOLA	CAVE SPIDER	SE	**	S1	GU
ITUNI60010	PSEUDOPOLYDESMUS COLLINUS	MILLIPEDE	SE	**	S1	G4
ITUNI03140	PSEUDOTREMIA NEFANDA	CAVE MILLEPEDE	SE	**	S1	G?
IICLL05060	SINELLA ALATA	SPRINGTAIL	SE	**	S2	G?
IPTUR04070	SPHALLOPLANA CHANDLERI	CHANDLER'S CAVE FLATWORM	SE	**	S1	G1
IPTUR04090	SPHALLOPLANA WEINGARTNERI	WEINGARTNER'S CAVE FLATWORM	ST	**	S2	G2G3

STATE: SX-extirpated. SE-endangered. ST-threatened. SR-rare. SSC-special concern. WL-watch SG-significant. SRE-state reintroduced

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Exotic Species in the Great Lakes Region

Biodiversity | Habitat | Plants | Publications | State Management Plans | Select Exotic Species | Task Forces | Wildlife

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An Overview of Exotic Species

Exotic species have threatened the Great Lakes ever since Europeans settled in the region. Since the 1800s, at least 136 exotic aquatic organisms of all types - including plants, fish, algae and mollusks - have become established in the Great Lakes. As human activity has increased in the Great Lakes watershed, the rate of introduction of exotic species has increased. More than one-third of the organisms have been introduced in the past 30 years, a surge coinciding with the opening of the St. Lawrence Seaway.

Select Exotic Species

Mollusks

- Zebra Mussel

Crustaceans

- Rusty Crayfish
- Spiny Water Flea

Fish

- Common Carp
- Goby
- Ruffe
- Sea Lamprey
- White Perch

Plants

- Curly-leaf Pondweed
- Eurasian Watermilfoil
- Flowering Rush
- Purple Loosestrife

Recommended Resources

Biological Pollution, Northeast-Midwest Institute
    The institute is undertaking a number of efforts to prevent the introduction and spread of nonindigenous aquatic nuisance species.
Exotic Species, Minnesota Sea Grant

State of Michigan
DEQ
Department of Environmental Quality
OFFICE OF THE GREAT LAKES

Nonindigenous Aquatic Nuisance Species State Management Plan:

A Strategy to Confront Their Spread in Michigan

Table of Contents

Appendix A

I. Executive Summary

Nonindigenous species are plants and animals found beyond their natural ranges and are now part of the North American landscape. Many are highly beneficial. Most U.S. crops and domesticated animals, many sport fish and aquaculture species, numerous horticultural plants, and most biological control organisms have origins outside Michigan. A large number of nonindigenous species, however, cause significant environmental, socio-economic, and public health damage. The severity of these impacts are not widely recognized, impeding the commitment needed to prevent future introductions. Also, a "crisis response" mentality often limits the vision and opportunity for the prevention of future introductions, leaving the state with control problems that are economically costly, technically challenging, often impossible to solve. Although at least 139 nonindigenous aquatic species have already become established in the Great Lakes ecosystem, future introductions are still highly probable. It is the harmful aquatic nuisance species (ANS), such as the zebra mussel, ruffe, goby, spiny water flea, Eurasian watermilfoil and others that arrived here unexpectedly, which provide the focal point for this State Management Plan (plan).The prevention of unintended introduction is critical in alleviating ANS problems in Michigan and the entire Great Lakes region.

The 1994 summer beach closings on Lake St. Clair, resulting from bacterial contamination and the massive accumulation of aquatic vegetation is a reminder that ecosystems can undergo dramatic changes due, in part, to the introduction of ANS into the Great Lakes Basin. Many changes in Lake St. Clair are attributed to increased water clarity, resulting from the presence of zebra mussels believed to have arrived in 1986.

We cannot completely stop the tide. Perfect screening, detection, and control are impossible for the foreseeable future. Nevertheless, Federal and State policies, designed to protect us from unplanned invasions and the spread of nonindigenous species, are not safeguarding our local and national interests in important areas. The conclusions of a report filed by the Office of Technology Assessment within the United States Congress (Harmful Non-Indigenous Aquatic Nuisance Species in the United States, September 1993) have a number of policy implications. First, the Nation has no real national policy on harmful aquatic introductions; and the current systems are piecemeal and lack adequate rigor and comprehensiveness. Second, many Federal and State statutes, regulations, and programs are not keeping pace with new and spreading nonindigenous pests. Third, better environmental education and greater accountability regarding actions that cause harm could prevent some problems. Finally, faster response and more adequate funding could limit the impact of those that slip through.

The Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (Public Law 101-646), is the federal legislation which calls upon the states to develop and implement comprehensive state management plans for aquatic nuisance species control. The Act was established for the prevention and control of the unintentional introduction of ANS and is based on the following five objectives:

- Prevent further unintentional introductions of nonindigenous aquatic species;
- Coordinate federally funded research, control efforts and information dissemination;
- Develop and carry out environmentally sound control methods to prevent, monitor and control unintentional introductions;
- Understand and minimize economic and ecological damage;
- Establish a program of research and technology development to assist state governments.

The plan requests funding in the amount of $466,700 over a three-year period and would provide the resources necessary for enhanced information and education efforts, additional monitoring capabilities, and increased technical assistance to private facilities. The resources would also be used for the development of policy options regarding environmental controls and regulations to provide the foundation for a long-term commitment to ANS control in Michigan. In addition, the plan sends the message that the federal government has not met its responsibility to control further introductions of ANS. Existing resources do not adequately address the problem.

While the opportunity for federal funding provided the initial impetus for the development of this plan, it will serve as Michigan's plan of action, to the extent resources allow, even if federal support fails to materialize.

II. The Present State of Affairs

Nonindigenous aquatic species are a source of socio-economic benefits and costs to many sectors of American society and a threat to the maintenance of biological diversity and ecological integrity. The significance of nonindigenous species issues are generally not recognized. Yet, the stakes are hard to overstate. An aquatic nuisance species (ANS) is defined as a waterborne, non-indigenous organism that threatens the diversity or abundance of native species, or the ecological stability of impacted waters, or, that threatens a commercial, agricultural, aquacultural or recreational activity dependent on infested waters. These species have the potential to cause significant ecological problems because they have been introduced into a habitat in which there are no natural controls, such as pathogens, parasites, and predators. Lack of natural controls in a new habitat may allow a species to grow at or near its potential, exponential growth rate. If such species become established, they may disrupt species relationships in the new habitat. As a nuisance species proliferates, other species relationships change in the habitat. The introduced species may prey upon, outcompete, or cause disease in native species.

Because the Great Lakes are open to the St. Lawrence Seaway for shipping, they have been the recipient of many foreign aquatic nuisance species. Since the 1800's, over 130 such organisms have become established in the Great Lakes Basin. Over one-third of the organisms have been introduced unintentionally in the past 30 years, a surge coinciding with the opening of the St. Lawrence Seaway. With the increased speed of ocean transport and improved water quality conditions in some European countries, zebra mussels, ruffe, gobies, and other pests are now able to survive the journey in ship ballast water from Europe to the Great Lakes. Nonindigenous aquatic nuisance species will continue to arrive in the Great Lakes Basin until the pathways by which these species are introduced are adequately addressed by federal, state, and provincial governments, and responsible actions are taken to reduce the rate of introduction. Nonindigenous species, and the control of their spread, are international issues with potential impacts that span economic, social, health, and ecological concerns. Water used for many applications, including ballast control, food processing, bait industry, exotic pet trade, and the aquarium trade are all sources of introduction of nonindigenous species causing adverse impacts to the Great Lakes.

On November 29, 1990, partly in response to the introduction of zebra mussels into the Great Lakes, Congress passed the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (Public Law 101-646). The major focus of the act is to set up a framework to reduce the risk of unintentional introductions and to monitor and control nonindigenous aquatic nuisance species. The act establishes a federal interagency Aquatic Nuisance Species Task Force responsible for developing a framework to address the problem of nonindigenous aquatic nuisance species. The act also contains specific provisions for controlling zebra mussels and a mandate that the United States Coast Guard promulgate ballast regulations which apply to vessels that enter a United States port on the Great Lakes after operating on the waters beyond the Exclusive Economic Zone (EEZ). The EEZ is defined as an area extending from the baseline of the territorial sea of the United States seaward 200 miles. The Coast Guard ballast water management regulations became effective on May 10, 1993. Because the regulations do not address ballast control measures for vessels operating inside the EEZ, and those entering Great Lakes connected fresh and brackish waters, it provides no safeguards for preventing the dispersion of aquatic nuisance species already established in the United States. The key to the long-term protection of the Great Lakes from unwanted arrivals is to prevent the discharge of ANS contaminated vessel ballast water into the Lakes. Cost effectiveness dictates that the strategic emphasis be placed on prevention of introductions rather than on attempting after-the-fact control of range expansions of ANS. An established nonindigenous organism in the Great Lakes Ecosystem is impossible to eradicate.

Section 1204 of the act is also particularly relevant to the Great Lakes States. This section allows the governor of each state, after notice and opportunity for public comment, to prepare and submit to the nationally appointed Aquatic Nuisance Species Task Force, a comprehensive state management plan which identifies management measures and funding needed to reduce infestations of aquatic nuisance species. Furthermore, development of a state management plan is a key recommendation of Michigan Natural Resources Commission Policy #2001 (Nonindigenous Aquatic Nuisance Species, March, 1993). The plan contained herein requests funding in the amount of $466,700 over a three-year period to carry out the following objectives:

- Prevent new introductions of ANS into the Great Lakes and inland waters of Michigan.
- Limit the spread of established populations of ANS into uninfested waters of Michigan.
- Abate harmful ecological, economic, social and public health impacts resulting from infestation of ANS.

The environmental and economic costs resulting from the invasion of aquatic nuisance species in Michigan will continue to rise if new introductions continue and with the spread of species already released. While the opportunity for federal funding provided the initial impetus for the development of this plan, it will serve as Michigan's plan of action, to the extent resources allow, even if federal support fails to materialize.

Species of Concern

The invasion of the zebra mussel in 1988 helped bring the serious nature of the aquatic nuisance species issue to the public eye. Prior to the zebra mussel invasion, public perception held that resource management agencies have the ability to control alien invaders. While this belief is partially true, control can only be defined as slowing or preventing the spread; range reduction of a species; mitigation of site specific conditions such as allowing for the treatment of water intake systems to remove colonies of zebra mussels; or cleaning beaches after major storm events which wash thousands of dead zebra mussels ashore. Control of aquatic nuisance species is not complete eradication of the nuisance organism from the ecosystem, rather it means a reduction in abundance or effect of the nuisance.

In the spring of 1988, the zebra mussel (Dreissena polymorpha) was discovered in Lake St. Clair. Scientists believe the zebra mussel was transported to North America in the ballast water of a transatlantic freighter that previously visited a port in Eastern Europe where this mollusk is common. Zebra mussels have now spread to all five Great Lakes and are also found in the Mississippi, Tennessee, Hudson, and Ohio River Basins.

Zebra mussels readily attach to most submerged surfaces including boats, rocky shoals, water intake pipes, navigational buoys, docks, piers, and indigenous species such as clams. They affix themselves to shells of their own species and are able to form dense layered colonies of over 1 million per square meter. The mussels have been able to colonize and foul heat exchangers, valves, and small diameter piping once the organism gains entry into power plants. Irrigation, fire protection, and dust suppression systems have also experienced problems associated with mussel colonization. The U.S. Fish and Wildlife Service assesses the potential economic impact at $5 billion over the next ten years to U.S. and Canadian factories, water suppliers, power plants, ships and fisheries within the Great Lakes Region.

The ability of zebra mussels to filter suspended particles with high efficiency from the water column was established by European researchers. Consequently, one of the early concerns regarding the appearance of zebra mussels in the Great Lakes was the impact on water quality. During the past several years research in the Western and Central Basins of Lake Erie has confirmed preliminary observations that water clarity had increased as a result of filtering activity by dense populations of zebra mussels. However, attributing an increase in clarity to zebra mussels is not as simple and straightforward as it may appear. Other important factors influence water clarity, such as storms that resuspend sediments, nutrients, phytoplankton, and organisms that graze on phytoplankton.

Over the past few decades, nutrients (especially phosphorus) that support phytoplankton growth have been an important determinant of water clarity in Lake Erie. High phosphorus levels support dense populations of algae, causing reduced water clarity. Since the 1960's improved sewage treatment facilities and low-phosphate detergents have successfully reduced phosphorus inputs to Lake Erie by about 50 percent. Researchers from the Ontario Ministry of the Environment recorded the decline of phytoplankton associated with decreasing phosphorous levels from the late 1960's to the present. With the appearance of zebra mussels in 1988, phytoplankton abundance declined significantly and far more rapidly than could be explained by declining phosphorous levels. A decline of phytoplankton also followed the spread of zebra mussels into Lake St. Clair in 1988, western Lake Erie in 1989, and central Lake Erie in 1990. An additional piece of evidence supports the role of zebra mussels in the decline of phytoplankton. The species composition of the phytoplankton community itself also changed. Researchers noted that as phosphorus levels declined, the dominant species of phytoplankton shifted from a blue-green algal community (high phosphorus) to a green algal community (lower phosphorus levels).

The consequences for organisms that rely on phytoplankton as a food source have yet to be accurately determined. Because phytoplankton is the major food source for open water (pelagic) lake food chains, fisheries impacts may result from zebra mussel filtration activity. Excessive removal of phytoplankton from the water column may cause a decline in planktivorous fish species. As a result, populations of planktivorous fish like gizzard shad might decline, and other desirable fishes such as walleye rely on the shad for forage. As zebra mussels settle and attach to firm substrates, there is also concern that extensive colonization of shoal areas in lakes could impair reproduction of certain fish species. The walleye and lake trout are two species which use rocky substrate for spawning and may be affected by colonies of mussels.

One severe biological impact that has been documented is the near extinction of native American unionid clams in Lake St. Clair and in the western basin of Lake Erie. Zebra mussels attach and build colonies on the clams, eventually leading to their death. One of the earliest and most noticeable natural responses is the increased use by diving ducks of areas with large populations of zebra mussels. Diving ducks feed on zebra mussels. Researchers do not believe that feeding of diving ducks alone will significantly reduce zebra mussel populations, however. The zebra mussels' prolific reproductive cycle along with its ability to adapt to many aquatic environments make it a very successful invader. Scientists believe eradication of the mussel is unlikely. Furthermore, American and Canadian research conducted since 1988, indicate an inevitable dispersion of zebra mussels to every temperate waterbody throughout North America.

Another important aquatic nuisance species already established in the Great Lakes Basin is the ruffe (Gymnocephalus cernuus), a small perch-like, Eurasian fish. It was apparently introduced to the Great Lakes in the St. Louis River near Duluth, Minnesota from a ballast discharge. In Europe the ruffe feeds on whitefish eggs and competes with other more desirable fish. The spiny dorsal fins of the ruffe discourage predation by other fish. In Lake Superior, the species of fish that is most affected by the ruffe is the yellow perch. Populations of perch have declined up to 75% in water bodies where ruffe have become established.

The quagga mussel (Dreissena bugensis) is related to the zebra mussel but is a distinct species. It prefers deeper, colder waters which is consistent with laboratory studies indicating that the quagga has a lower thermal maximum than the zebra mussel. In addition, it may have the same potential as the zebra mussel to clog water intakes. The discovery of this second type of mussel increases the probability that other species of Dreissenidae have been introduced into the Great Lakes.

The round goby (Neogobius melanostomus)is an abundant species with origins in the Black and Caspian Seas. They are a small fish that feed chiefly on bivalves, amphipod crustaceans, small fish, and fish eggs. It is also believed this fish was introduced into the Great Lakes from discharged ballast water. Consumption studies of fish suggests round gobies might have a detrimental impact on native species through competition for food and predation on eggs and young fish.

The spiny water flea (Bythotrephes cederstroemi)is also believed to have entered the waters of the Great Lakes from discharged ballast water. Although its average length is rarely more than one centimeter, this large predaceous zooplankter can have a profound effect on a lake's plankton. The spiny water flea sometimes competes directly with young fish for food. Because this organism can reproduce many times faster than fish, it could monopolize the food supply at times, to the eventual detriment of the fish. Although Bythotrephes can also fall prey to fish, its spine seems to frustrate most small fish, which experience great difficulty swallowing the animal.

The sea lamprey (Petromyzon marinus) has been a serious problem in the Great Lakes for more than 50 years. After more than 30 years of trying to eradicate lamprey, the parasitic invader is making a comeback at the expense of the lake trout fishery in northern Lakes Michigan and Huron. An adult lamprey can kill up to 40 pounds of fish in just 12 to 20 months. A lamprey attaches itself to a fish with a sucking disk, pierces its scales and skin and sucks out body fluids, often killing the fish.

Eurasian watermilfoil (Myriophyllum spicatum), a nonindigenous aquatic plant, reached the midwestern states between the 1950s and 1980s. In nutrient rich lakes watermilfoil can form thick underwater stands of tangled stems and vast mats of vegetation at the water's surface. In shallow areas the plant can interfere with water recreation such as boating, fishing, and swimming. The plant's floating canopy can also crowd out dominant native water plants.

Purple Loosestrife (Lythrum salicaria), is a perennial wetland plant native to Europe and Asia. It was introduced into the United States in the early 1800s and continues to spread. The plant is impacting Michigan wetland ecosystems by changing the structure, function, and productivity of the wetlands. The plant forms dense monoculture stands, sometimes hundreds of acres in size, that displace native vegetation and threaten the biotic integrity of wetland ecosystems. The loss of plant species richness and diversity has eliminated natural foods and cover essential to many wetland wildlife species.

Once established in large, open aquatic systems, harmful, nonindigenous species such as those described above have proven impossible to eradicate. These species represent only a small percentage of the most

Public Comment Period

On March 10, 1995, Michigan's Nonindigenous Aquatic Nuisance Species State Management Plan was made available for a 45-day public review and comment period. Notice of the availability of the plan was announced in a statewide press release and in the Department of Natural Resources Calendar. Three hundred copies were printed and all were subsequently distributed. Written comments were received from twenty-six individuals representing fifteen different agencies and organizations. To the extent possible, the comments were addressed and information incorporated in the final document. A summary of the public comments can be obtained by contacting the Office of the Great Lakes. In addition, questions or comments about the State Management Plan should be directed to the Office at 517-373-3588.

Document prepared by Mark Coscarelli, Environmental Specialist, Office of the Great Lakes.

Appendix A

Referenced Materials

The following documents were used in the development of the information presented in this plan.

U.S. Congress, Office of Technology Assessment, *Harmful Nonindigenous Species in the United States*, OTA-F-565 (Washington, DC: U.S. Government Printing Office, September 1993).

International Joint Commission and the Great Lakes Fishery Commission, *Exotic Species and the Shipping Industry: The Great Lakes-St. Lawrence Ecosystem at Risk*, (A special report to the Governments of the United States and Canada, September 1990).

Marine Technology and the Environment, *The Ship As a Vector in Biotic Invasions*, (IMAS 90, May 1990).

United States Coast Guard, *The Defense of the Great Lakes against the Invasion of Nonindigenous Species in Ballast Water*, (Compliance Overview of Ballast Water Regulations, September 2, 1995).

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Questions or Comments?
Contact Martha Waszak (517) 335-4112 FAX: (517) 335-4053
e-mail address: waszakm@deq.state.mi.us

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Revised December 18, 1996, by Martha Waszak
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